

# Creativity

Anoiko 2011

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# Intelligence

**Intelligence** is a term describing one or more capacities of the mind. In different contexts this can be defined in different ways, including the capacities for abstract thought, understanding, communication, reasoning, learning, planning, emotional intelligence and problem solving.

Intelligence is most widely studied in humans, but is also observed in animals and plants. Artificial intelligence is the intelligence of machines or the simulation of intelligence in machines.

Numerous definitions of and hypotheses about intelligence have been proposed since before the twentieth century, with no consensus reached by scholars. Within the discipline of psychology, various approaches to human intelligence have been adopted. The psychometric approach is especially familiar to the general public, as well as being the most researched and by far the most widely used in practical settings.<sup>[1]</sup>

## History of the term

Intelligence derives from the Latin verb *intelligere* which derives from *inter-legere* meaning to "pick out" or discern. A form of this verb, *intellectus*, became the medieval technical term for understanding, and a translation for the Greek philosophical term *nous*. This term was however strongly linked to the metaphysical and cosmological theories of teleological scholasticism, including theories of the immortality of the soul, and the concept of the Active Intellect (also known as the Active Intelligence). This entire approach to the study of nature was strongly rejected by the early modern philosophers such as Francis Bacon, Thomas Hobbes, John Locke, and David Hume, all of whom preferred the word "understanding" in their English philosophical works.<sup>[2] [3]</sup> Hobbes for example, in his Latin *De Corpore*, used "*intellectus intelligit*" (translated in the English version as "the understanding understandeth") as a typical example of a logical absurdity.<sup>[4]</sup> The term "intelligence" has therefore become less common in English language philosophy, but it has later been taken up (without the scholastic theories which it once implied) in more contemporary psychology.

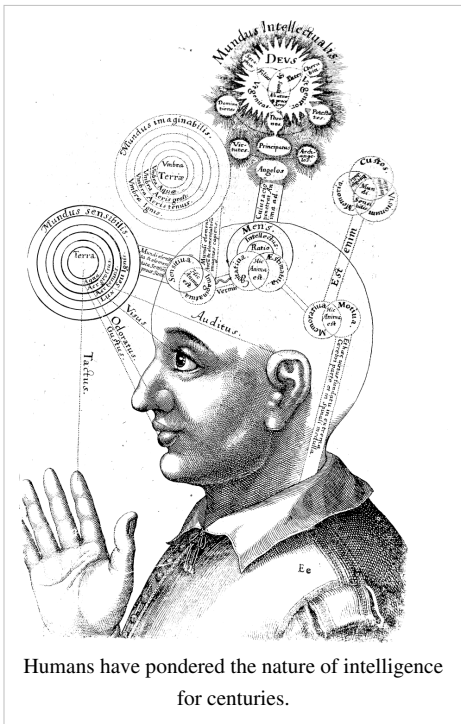
## Definitions

How to define intelligence is controversial. Groups of scientists have stated the following:

1. from "Mainstream Science on Intelligence" (1994), an editorial statement by fifty-two researchers:

A very general mental capability that, among other things, involves the ability to reason, plan, solve problems, think abstractly, comprehend complex ideas, learn quickly and learn from experience. It is not merely book learning, a narrow academic skill, or test-taking smarts. Rather, it reflects a broader and deeper capability for comprehending our surroundings—"catching on," "making sense" of things, or "figuring out" what to do.<sup>[5]</sup>

2. from "Intelligence: Knowns and Unknowns" (1995), a report published by the Board of Scientific Affairs of the American Psychological Association:



Humans have pondered the nature of intelligence for centuries.



Individuals differ from one another in their ability to understand complex ideas, to adapt effectively to the environment, to learn from experience, to engage in various forms of reasoning, to overcome obstacles by taking thought. Although these individual differences can be substantial, they are never entirely consistent: a given person's intellectual performance will vary on different occasions, in different domains, as judged by different criteria. Concepts of "intelligence" are attempts to clarify and organize this complex set of phenomena. Although considerable clarity has been achieved in some areas, no such conceptualization has yet answered all the important questions, and none commands universal assent. Indeed, when two dozen prominent theorists were recently asked to define intelligence, they gave two dozen, somewhat different, definitions.<sup>[6] [7]</sup>

Besides the foregoing definitions, these psychology and learning researchers also have defined intelligence as:

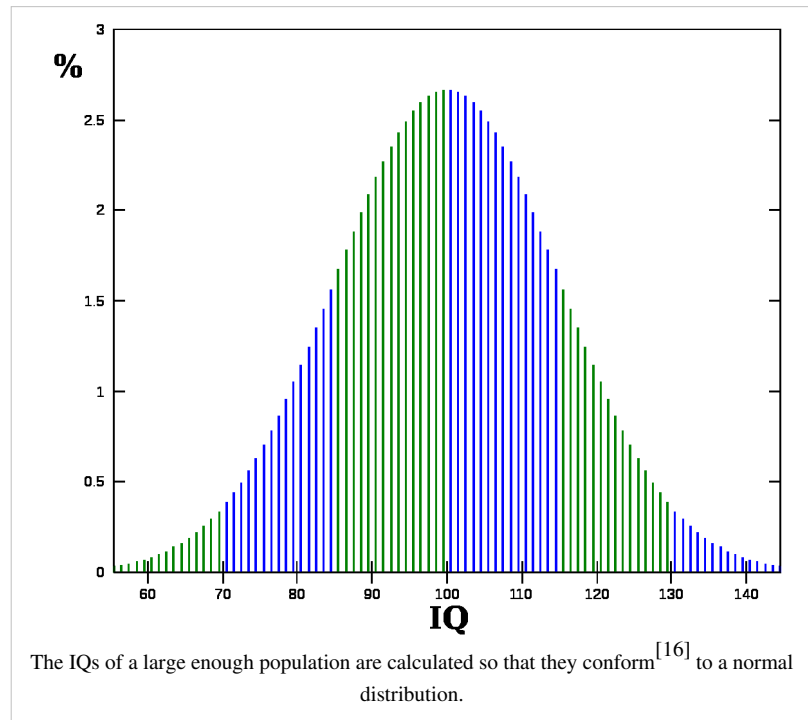
Researcher	Quotation
Alfred Binet	Judgment, otherwise called "good sense," "practical sense," "initiative," the faculty of adapting one's self to circumstances ... auto-critique. <sup>[8]</sup>
David Wechsler	The aggregate or global capacity of the individual to act purposefully, to think rationally, and to deal effectively with his environment. <sup>[9]</sup>
Cyril Burt	Innate general cognitive ability <sup>[10]</sup>
Howard Gardner	To my mind, a human intellectual competence must entail a set of skills of problem solving — enabling the individual to resolve genuine problems or difficulties that he or she encounters and, when appropriate, to create an effective product — and must also entail the potential for finding or creating problems — and thereby laying the groundwork for the acquisition of new knowledge. <sup>[11]</sup>
Linda Gottfredson	The ability to deal with cognitive complexity. <sup>[12]</sup>
Sternberg & Salter	Goal-directed adaptive behavior. <sup>[13]</sup>
Reuven Feuerstein	The theory of Structural Cognitive Modifiability describes intelligence as "the unique propensity of human beings to change or modify the structure of their cognitive functioning to adapt to the changing demands of a life situation." <sup>[14]</sup>

What is considered intelligent varies with culture. For example, when asked to sort, the Kpelle people take a functional approach. A Kpelle participant stated "the knife goes with the orange because it cuts it." When asked how a fool would sort, they sorted linguistically, putting the knife with other implements and the orange with other foods, which is the style considered intelligent in other cultures.<sup>[15]</sup>

## Human intelligence

### Psychometrics

The approach to understanding intelligence with the most supporters and published research over the longest period of time is based on psychometric testing. It is also by far the most widely used in practical settings. Intelligence quotient (IQ) tests include the Stanford-Binet, Raven's Progressive Matrices, the Wechsler Adult Intelligence Scale and the Kaufman Assessment Battery for Children. There are also psychometric tests which are not intended to measure intelligence itself but some closely related construct such as scholastic aptitude. In the United States examples include the SSAT, the SAT, the ACT, the GRE, the MOAT, the LSAT, and the GMAT.<sup>[1]</sup>



Intelligence tests are widely used in educational, business, and military settings due to their efficacy in predicting behavior. IQ and  $g$  (discussed in the next section) are correlated with many important social outcomes—individuals with low IQs are more likely to be divorced, have a child out of marriage, be incarcerated, and need long-term welfare support, while individuals with high IQs are associated with more years of education, higher status jobs and higher income.<sup>[17]</sup> Intelligence is significantly correlated with successful training and performance outcomes, and IQ/ $g$  is the single best predictor of successful job performance.<sup>[18] [1]</sup>

### General intelligence or $g$

There are many different kinds of IQ tests using a wide variety of test tasks. Some tests consist of a single type of task, others rely on a broad collection of tasks with different contents (visual-spatial, verbal, numerical) and asking for different cognitive processes (e.g., reasoning, memory, rapid decisions, visual comparisons, spatial imagery, reading, and retrieval of general knowledge). The psychologist Charles Spearman early in the 20th century carried out the first formal factor analysis of correlations between various test tasks. He found a trend for all such tests to correlate positively with each other, which is called a *positive manifold*. Spearman found that a single common factor explained the positive correlations among test. Spearman named it  $g$  for "general intelligence factor". He interpreted it as the core of human intelligence that, to a larger or smaller degree, influences success in all cognitive tasks and thereby creates the positive manifold. This interpretation of  $g$  as a common cause of test performance is still dominant in psychometrics. An alternative interpretation was recently advanced by van der Maas and colleagues<sup>[19]</sup>. Their *mutualism model* assumes that intelligence depends on several independent mechanisms, none of which influences performance on all cognitive tests. These mechanisms support each other so that efficient operation of one of them makes efficient operation of the others more likely, thereby creating the positive manifold.

IQ tasks and tests can be ranked by how highly they load on the  $g$  factor. Tests with high  $g$ -loadings are those that correlate highly with most other tests. One comprehensive study investigating the correlations between a large collection of tests and tasks<sup>[20]</sup> has found that the Raven's Progressive Matrices have a particularly high correlation

with most other tests and tasks. The *Raven's* is a test of inductive reasoning with abstract visual material. It consists of a series of problems, sorted approximately by increasing difficulty. Each problem presents a 3 x 3 matrix of abstract designs with one empty cell; the matrix is constructed according to a rule, and the person must find out the rule to determine which of 8 alternatives fits into the empty cell. Because of its high correlation with other tests, the Raven's Progressive Matrices are generally acknowledged as a good indicator of general intelligence. This is problematic, however, because there are substantial gender differences on the *Raven's* <sup>[21]</sup>, which are not found when *g* is measured directly by computing the general factor from a broad collection of tests <sup>[22]</sup>.

### Historical psychometric theories

Several different theories of intelligence have historically been important. Often they emphasized more factors than a single one like in *g*

### Cattell-Horn-Carroll theory

Many of the broad, recent IQ tests have been greatly influenced by the Cattell-Horn-Carroll theory. It is argued to reflect much of what is known about intelligence from research. A hierarchy of factors is used. *g* is at the top. Under it there are 10 broad abilities that in turn are subdivided into 70 narrow abilities. The broad abilities are:<sup>[23]</sup>

- Fluid Intelligence (Gf): includes the broad ability to reason, form concepts, and solve problems using unfamiliar information or novel procedures.
- Crystallized Intelligence (Gc): includes the breadth and depth of a person's acquired knowledge, the ability to communicate one's knowledge, and the ability to reason using previously learned experiences or procedures.
- Quantitative Reasoning (Gq): the ability to comprehend quantitative concepts and relationships and to manipulate numerical symbols.
- Reading & Writing Ability (Grw): includes basic reading and writing skills.
- Short-Term Memory (Gsm): is the ability to apprehend and hold information in immediate awareness and then use it within a few seconds.
- Long-Term Storage and Retrieval (Glr): is the ability to store information and fluently retrieve it later in the process of thinking.
- Visual Processing (Gv): is the ability to perceive, analyze, synthesize, and think with visual patterns, including the ability to store and recall visual representations.
- Auditory Processing (Ga): is the ability to analyze, synthesize, and discriminate auditory stimuli, including the ability to process and discriminate speech sounds that may be presented under distorted conditions.
- Processing Speed (Gs): is the ability to perform automatic cognitive tasks, particularly when measured under pressure to maintain focused attention.
- Decision/Reaction Time/Speed (Gt): reflect the immediacy with which an individual can react to stimuli or a task (typically measured in seconds or fractions of seconds; not to be confused with Gs, which typically is measured in intervals of 2-3 minutes). See Mental chronometry.

Modern tests do not necessarily measure of all of these broad abilities. For example, Gq and Grw may be seen as measures of school achievement and not IQ.<sup>[23]</sup> Gt may be difficult to measure without special equipment.

*g* was earlier often subdivided into only Gf and Gc which were thought to correspond to the Nonverbal or Performance subtests and Verbal subtests in earlier versions of the popular Wechsler IQ test. More recent research has shown the situation to be more complex.<sup>[23]</sup>

## Controversies

While not necessarily a dispute about the psychometric approach itself, there are several controversies regarding the results from psychometric research. Examples being the role of genetics vs. environment, the causes of average group differences, or the Flynn effect.

One criticism has been against the early research such as craniometry.<sup>[24]</sup> A reply has been that drawing conclusions from early intelligence research is like condemning the auto industry by criticizing the performance of the Model T.<sup>[25]</sup>

Several critics, such as Stephen Jay Gould, have been critical of *g*, seeing it as a statistical artifact, and that IQ tests instead measure a number of unrelated abilities.<sup>[26]</sup> <sup>[24]</sup> The American Psychological Association's report "Intelligence: Knowns and Unknowns" stated that IQ tests do correlate and that the view that *g* is a statistical artifact is a minority one.

## Other theories

There are critics of IQ, who do not dispute the stability of IQ test scores or the fact that they predict certain forms of achievement rather effectively. They do argue, however, that to base a concept of intelligence on IQ test scores alone is to ignore many important aspects of mental ability.<sup>[1]</sup>

On the other hand, Linda S. Gottfredson (2006) has argued that the results of thousands of studies support the importance of IQ for school and job performance. IQ also predicts or correlates with numerous other life outcomes. In contrast, empirical support for non-*g* intelligences is lacking or very poor. She argued that despite this the ideas of multiple non-*g* intelligences are very attractive to many due to the suggestion that everyone can be smart in some way.<sup>[27]</sup>

## Multiple intelligences

Howard Gardner's theory of multiple intelligences is based on studies not only of normal children and adults but also by studies of gifted individuals (including so-called "savants"), of persons who have suffered brain damage, of experts and virtuosos, and of individuals from diverse cultures. This led Gardner to break intelligence down into at least eight different components: logical, linguistic, spatial, musical, kinesthetic, interpersonal, intrapersonal, naturalist and existential intelligences. He argues that psychometric tests address only linguistic and logical plus some aspects of spatial intelligence. A major criticism of Gardner's theory is that it has never been tested, or subjected to peer review, by Gardner or anyone else, and indeed that it is unfalsifiable.<sup>[28]</sup>

## Triarchic theory of intelligence

Robert Sternberg proposed the triarchic theory of intelligence to provide a more comprehensive description of intellectual competence than traditional differential or cognitive theories of human ability.<sup>[29]</sup> The triarchic theory describes three fundamental aspects of intelligence. Analytic intelligence comprises the mental processes through which intelligence is expressed. Creative intelligence is necessary when an individual is confronted with a challenge that is nearly, but not entirely, novel or when an individual is engaged in automatizing the performance of a task. Practical intelligence is bound in a sociocultural milieu and involves adaptation to, selection of, and shaping of the environment to maximize fit in the context. The triarchic theory does not argue against the validity of a general intelligence factor; instead, the theory posits that general intelligence is part of analytic intelligence, and only by considering all three aspects of intelligence can the full range of intellectual functioning be fully understood.

More recently, the triarchic theory has been updated and renamed the Theory of Successful Intelligence by Sternberg.<sup>[30]</sup> <sup>[31]</sup> Intelligence is defined as an individual's assessment of success in life by the individual's own (idiographic) standards and within the individual's sociocultural context. Success is achieved by using combinations of analytical, creative, and practical intelligence. The three aspects of intelligence are referred to as processing skills. The processing skills are applied to the pursuit of success through what were the three elements of practical

intelligence: adapting to, shaping of, and selecting of one's environments. The mechanisms that employ the processing skills to achieve success include utilizing one's strengths and compensating or correcting for one's weaknesses.

Sternberg's theories and research on intelligence remain contentious within the scientific community.<sup>[32] [33] [34] [35]</sup>

### **Piaget's theory and Neo-Piagetian theories**

In Piaget's theory of cognitive development the focus is not on mental abilities but rather on a child's mental models of the world. As a child develops, increasingly more accurate models of the world are developed which enable the child to interact with the world better. One example being object permanence where the child develops a model where objects continue to exist even when they cannot be seen, heard, or touched.

Piaget's theory described four main stages and many sub-stages in the development. Degree of progress through these is correlated with but is not identical with psychometric IQ.<sup>[36] [37]</sup>

Neo-Piagetian theories of cognitive development expand Piaget's theory in various ways such as also considering psychometric-like factors such as processing speed and working memory, "hypercognitive" factors like self-monitoring, more stages, and more consideration on how progress may vary in different domains such as spatial or social.<sup>[38] [39]</sup>

Piaget's theory has been criticized for the age of appearance of a new model of the world, such as object permanence, being dependent on how the testing is done (see the article on object permanence). More generally, the theory may be very difficult to test empirically due to the difficulty of proving or not proving that a mental model is the explanation for the results of the testing.<sup>[40]</sup>

### **Emotional intelligence**

Emotional intelligence is an argued ability, capacity, skill or, a self-perceived ability to identify, assess, and control the emotions of oneself, of others, and of groups. Different models have been proposed for the definition of emotional intelligence and there is disagreement about how the term should be used. The concept is controversial, with some seeing it as a skill or form of personality rather than intelligence, and its predicative ability, especially after controlling for the effects of IQ and the Big Five personality traits, is disputed.

### **Latent inhibition**

Latent inhibition has been related to elements of intelligence, namely creativity and genius.

### **Evolution of intelligence**

Our hominid and human ancestors evolved large and complex brains exhibiting an ever-increasing intelligence through a long evolutionary process. Many different explanations have been proposed.

### **Improving intelligence**

Eugenics is a social philosophy which advocates the improvement of human hereditary traits through various forms of intervention.<sup>[41]</sup> Conscious efforts to influence intelligence raise ethical issues. Eugenics has variously been regarded as meritorious or deplorable in different periods of history, falling greatly into disrepute after the defeat of Nazi Germany in World War II.

Neuroethics considers the ethical, legal and social implications of neuroscience, and deals with issues such as the difference between treating a human neurological disease and enhancing the human brain, and how wealth impacts access to neurotechnology. Neuroethical issues interact with the ethics of human genetic engineering.

Because intelligence appears to be at least partly dependent on brain structure and the genes shaping brain development, it has been proposed that genetic engineering could be used to enhance the intelligence, a process sometimes called biological uplift in science fiction. Experiments on mice have demonstrated superior ability in

learning and memory in various behavioral tasks.<sup>[42]</sup>

Transhumanist theorists study the possibilities and consequences of developing and using techniques to enhance human abilities and aptitudes, and individuals ameliorating what they regard as undesirable and unnecessary aspects of the human condition.

### Factors associated with intelligence

A number of factors are known to correlate with IQ but since correlation does not imply causation the true relationship between these factors is uncertain unless there are also other forms of evidence. There are also group differences regarding IQ.

- Environment and intelligence
- Fertility and intelligence
- Flynn effect
- Health and intelligence
- Height and intelligence
- Heritability of IQ
- Longevity and intelligence
- Nations and intelligence
- Neuroscience and intelligence
- Race and intelligence
- Religiosity and intelligence
- Sex and psychology

### Animal and plant intelligence

Although humans have been the primary focus of intelligence researchers, scientists have also attempted to investigate animal intelligence, or more broadly, animal cognition. These researchers are interested in studying both mental ability in a particular species, and comparing abilities between species. They study various measures of problem solving, as well as mathematical and language abilities. Some challenges in this area are defining intelligence so that it means the same thing across species (e.g. comparing intelligence between literate humans and illiterate animals), and then operationalizing a measure that accurately compares mental ability across different species and contexts.



The common Chimpanzee can use tools. This chimpanzee is using a stick in order to get food.

Wolfgang Köhler's pioneering research on the intelligence of apes is a classic example of research in this area. Stanley Coren's book, *The Intelligence of Dogs* is a notable popular book on the topic.<sup>[43]</sup> Nonhuman animals particularly noted and studied for their intelligence include chimpanzees, bonobos (notably the language-using Kanzi) and other great apes, dolphins, elephants and to some extent parrots and ravens. Controversy exists over the extent to which these judgments of intelligence are accurate.

Cephalopod intelligence also provides important comparative study. Cephalopods appear to exhibit characteristics of significant intelligence, yet their nervous systems differ radically from those of most other notably intelligent life-forms (mammals and birds).

It has been argued that plants should also be classified as being intelligent based on their ability to sense the environment and adjust their morphology, physiology and phenotype accordingly.<sup>[44] [45]</sup>

## Artificial intelligence

Artificial intelligence (or AI) is both the intelligence of machines and the branch of computer science which aims to create it, through "the study and design of intelligent agents"<sup>[46]</sup> or "rational agents", where an intelligent agent is a system that perceives its environment and takes actions which maximize its chances of success.<sup>[47]</sup> Achievements in artificial intelligence include constrained and well-defined problems such as games, crossword-solving and optical character recognition. General intelligence or strong AI has not yet been achieved and is a long-term goal of AI research.

Among the traits that researchers hope machines will exhibit are reasoning, knowledge, planning, learning, communication, perception, and the ability to move and manipulate objects.<sup>[46] [47]</sup> In the field of artificial intelligence there is no consensus on how closely the brain should be simulated.



The artificial intelligence quiz show contestant "Watson", appearing on the US quiz show *Jeopardy!* in 2011.

## Intelligence in culture and arts

The concept of intelligence has been treated in many works:

- Flowers for Algernon, a book written by Daniel Keyes and published in 1966.

## References

- [1] Neisser, U.; Boodoo, G.; Bouchard, T. J. , J.; Boykin, A. W.; Brody, N.; Ceci, S. J.; Halpern, D. F.; Loehlin, J. C. et al. (1996). "Intelligence: Knowns and unknowns". *American Psychologist* **51**: 77. doi:10.1037/0003-066X.51.2.77. Article in Wikipedia: Intelligence: Knowns and Unknowns
- [2] Martinich, Aloysius (1995), *A Hobbes Dictionary*, Blackwell, p. 305
- [3] Niddich, Peter, "Foreward", *An Essay Concerning Human Understanding*, Oxford University Press, p. xxii
- [4] English (<http://www.archive.org/stream/englishworkstho21hobbgoog#page/n83/mode/1up/search/understanding>), and Latin version (<http://www.archive.org/stream/thomhobbesmalme03molegoog#page/n184/mode/1up/search/intellectus>).
- [5] Gottfredson, L.S. (1997). "Foreword to "intelligence and social policy"" (<http://www.udel.edu/educ/gottfredson/reprints/1997specialissue.pdf>) (pdf). *Intelligence* **24** (1): 1–12. doi:10.1016/S0160-2896(97)90010-6. Retrieved 2008-03-18.
- [6] Neisser, U.; Boodoo, G.; Bouchard Jr, T.J.; Boykin, A.W.; Brody, N.; Ceci, S.J.; Halpern, D.F.; Loehlin, J.C.; Perloff, R.; Sternberg, R.J.; Others, (1998). "Intelligence: Knowns and Unknowns" (<http://books.google.com/?id=gLWnmVbKdLwC&pg=PA95&dq=Intelligence:+Knowns+and+unknowns>). *Annual Progress in Child Psychiatry and Child Development 1997*. ISBN 9780876308707. Retrieved 2008-03-18.
- [7] Perloff, R.; Sternberg, R.J.; Urbina, S. (1996). "Intelligence: knowns and unknowns". *American Psychologist* **51**.
- [8] Binet, Alfred (1916) [1905]. "New methods for the diagnosis of the intellectual level of subnormals" (<http://psychclassics.asu.edu/Binet/binet1.htm>). *The development of intelligence in children: The Binet-Simon Scale*. E.S. Kite (Trans.). Baltimore: Williams & Wilkins. pp. 37–90. Retrieved 10 July 2010. "originally published as Méthodes nouvelles pour le diagnostic du niveau intellectuel des anormaux. L'Année Psychologique, 11, 191-244"
- [9] Wechsler, D (1944). *The measurement of adult intelligence*. Baltimore: Williams & Wilkins. ISBN 0195022963. OCLC 219871557 5950992. ASIN = B000UG9J7E
- [10] Burt, C. (1931). "The Differentiation Of Intellectual Ability". *The British Journal of Educational Psychology*.
- [11] *Frames of mind: The theory of multiple intelligences*. New York: Basic Books. 1993. ISBN 0465025102. OCLC 221932479 27749478 32820474 56327755 9732290.
- [12] Gottfredson, L. (1998). "The General Intelligence Factor" (<http://www.udel.edu/educ/gottfredson/reprints/1998generalintelligencefactor.pdf>) (pdf). *Scientific American Presents* **9** (4): 24–29. Retrieved 2008-03-18.
- [13] Sternberg RJ; Salter W (1982). *Handbook of human intelligence*. Cambridge, UK: Cambridge University Press. ISBN 0521296870. OCLC 11226466 38083152 8170650.

- [14] Feuerstein, R., Feuerstein, S., Falik, L & Rand, Y. (1979; 2002). Dynamic assessments of cognitive modifiability. ICELP Press, Jerusalem: Israel; Feuerstein, R. (1990). The theory of structural modifiability. In B. Presseisen (Ed.), Learning and thinking styles: Classroom interaction. Washington, DC: National Education Associations
- [15] Glick (1975) reported in Resnick, L. (1976). The Nature of Intelligence. Hillsdale, New Jersey: Lawrence Erlbaum Associates.
- [16] S.E. Embretson & S.P. Reise: Item response theory for psychologists, 2000. "...for many other psychological tests, normal distributions are achieved by normalizing procedures. For example, intelligence tests..." Found on: [http://books.google.se/books?id=rYU7rsi53gQC&pg=PA29&lpg=PA29&dq=%22intelligence+tests%22+normalize&source=bl&ots=ZAIQEgaa6Q&sig=q-amDaZqx7Ix6mMkvIDMnj9M9O0&hl=sv&ei=IEEJTNqSIYWMOPqLuRE&sa=X&oi=book\\_result&ct=result&resnum=7&ved=0CEIQ6AEwBg#v=onepage&q&f=false](http://books.google.se/books?id=rYU7rsi53gQC&pg=PA29&lpg=PA29&dq=%22intelligence+tests%22+normalize&source=bl&ots=ZAIQEgaa6Q&sig=q-amDaZqx7Ix6mMkvIDMnj9M9O0&hl=sv&ei=IEEJTNqSIYWMOPqLuRE&sa=X&oi=book_result&ct=result&resnum=7&ved=0CEIQ6AEwBg#v=onepage&q&f=false)
- [17] Geary, David M. (2004). *The Origin of the Mind: Evolution of Brain, Cognition, and General Intelligence*. American Psychological Association (APA). ISBN 1591471818. OCLC 217494183 222186498 224277260 224979556 54906982 56659187 57354730 80049339.
- [18] Ree, M.J.; Earles, J.A. (1992). "Intelligence Is the Best Predictor of Job Performance". *Current Directions in Psychological Science* **1** (3): 86–89. doi:10.1111/1467-8721.ep10768746.
- [19] van der Maas, H. L. J.; Dolan, C. V.; Grasman, R. P. P. P.; Wicherts, J. M.; Huizenga, H. M.; Raijmakers, M. E. J. (2006). "A dynamical model of general intelligence: The positive manifold of intelligence by mutualism". *Psychological Review* **113**: 842-861.
- [20] Marshalek, B.; Lohman, D. F. Snow, R. E. (1983). "The complexity continuum in the radex and hierarchical models of intelligence". *Intelligence* **7**: 107-127.
- [21] Lynnn, R.; Irving, P. (2004). "Sex differences on the progressive matrices: A meta-analysis.". *Intelligence* **32**: 481-498.
- [22] Halpern, D. F.; LaMay, M. L. (2000). "The smarter sex: A critical review of sex differences in intelligence". *Educational Psychology Review* **12**: 229-246.
- [23] IQ Testing 101, Alan S. Kaufman, 2009, Springer Publishing Company, ISBN-10: 0826106293 ISBN-13: 9780826106292
- [24] The Mismeasure of Man, Stephen Jay Gould, Norton, 1996
- [25] Jensen, A.R. (1942). "The debunking of scientific fossils and straw persons" (<http://www.debunker.com/texts/jensen.html>). *Contemporary Education Review* **1** (2): 121–135. . Retrieved 2008-03-18.
- [26] Schlinger, H.D. (2003). "The Myth of Intelligence" (<http://www.questia.com/PM.qst?a=o&se=ggjisc&d=5001903843>). *The Psychological Record* **53** (1): 15–33. . Retrieved 2008-03-18.
- [27] Gottfredson, L. S. (2006). Social consequences of group differences in cognitive ability (Consequencias sociais das diferencas de grupo em habilidade cognitiva). In C. E. Flores-Mendoza & R. Colom (Eds.), *Introducau a psicologia das diferencas individuais* (pp. 433-456). Porto Alegre, Brazil: ArtMed Publishers.
- [28] <http://www.cortland.edu/psych/mi/critique.html>
- [29] Sternberg, R.J. (1985). *Beyond IQ: A triarchic theory of human intelligence*. New York: Cambridge University Press. ISBN 0521262542.
- [30] Sternberg, R.J. (1978). "The theory of successful intelligence". *Review of General Psychology* **3**: 292–316. doi:10.1037/1089-2680.3.4.292.
- [31] Sternberg, R.J. (2003). "A broad view of intelligence: The theory of successful intelligence". *Consulting Psychology Journal: Practice & Research* **55**: 139–154. doi:10.1037/1061-4087.55.3.139.
- [32] Brody, N. (2003). "Construct validation of the Sternberg Triarchic Abilities Test: Comment and reanalysis". *Intelligence* **31**: 319–329. doi:10.1016/S0160-2896(01)00087-3.
- [33] Brody, N. (2003). "What Sternberg should have concluded". *Intelligence* **31**: 339–342. doi:10.1016/S0160-2896(02)00190-3.
- [34] Gottfredson, L.S. (2003). "Dissecting practical intelligence theory: Its claims and evidence". *Intelligence* **31**: 343–397. doi:10.1016/S0160-2896(02)00085-5.
- [35] Gottfredson, L.S. (2003). "On Sternberg's 'Reply to Gottfredson'". *Intelligence* **31**: 415–424. doi:10.1016/S0160-2896(03)00024-2.
- [36] Elkind, D., & Flavell, J. (1969). *Studies in cognitive development: Essays in honor of Jean Piaget*. New York: Oxford University Press
- [37] Intelligence and IQ, Landmark Issues and Great Debates, Richard A. Weinberg American Vol. 44, No. 2, 98-104
- [38] Demetriou, A. (1998). Cognitive development. In A. Demetriou, W. Doise, K.F.M. van Lieshout (Eds.), *Life-span developmental psychology* (pp. 179-269). London: Wiley.
- [39] Demetriou, A., Mouyi, A., & Spanoudis, G. (2010). The development of mental processing. Nesselroade, J.R. (2011). Methods in the study of life-span human development: Issues and answers. In W.F. Overton (Ed.), *Biology, cognition and methods across the life-span. Volume 1 of the Handbook of life-span development* (pp. 36-35), Editor-in-chief: R.M. Lerner. Hoboken, NJ: Wiley.
- [40] Kitchener, Richard F. (1993). "Piaget's epistemic subject and science education: Epistemological vs. Psychological issues". *Science and Education* **2** (2): 137–148. doi:10.1007/BF00592203.
- [41] Osborn, F. (1937). "Development of a Eugenic Philosophy" ([http://links.jstor.org/sici?sici=0003-1224\(193706\)2:3<389:DOAEP>2.0.CO;2-L](http://links.jstor.org/sici?sici=0003-1224(193706)2:3<389:DOAEP>2.0.CO;2-L)). *American Sociological Review* **2** (3): 389–397. doi:10.2307/2084871. . Retrieved 2010-03-20.
- [42] Tang YP, Shimizu E, Dube GR, et al. (1999). "Genetic enhancement of learning and memory in mice". *Nature* **401** (6748): 63–9. doi:10.1038/43432. PMID 10485705.
- [43] Coren, Stanley (1995). *The Intelligence of Dogs*. Bantam Books. ISBN 0-553-37452-4. OCLC 30700778.
- [44] Trewavas, Anthony (September 2005). "Green plants as intelligent organisms". *Trends in Plant Science* **10** (9): 413–419. doi:10.1016/j.tplants.2005.07.005. PMID 16054860.
- [45] Trewavas, A. (2002). "Mindless mastery". *Nature* **415** (6874): 841. doi:10.1038/415841a. PMID 11859344.
- [46] Goebel, Randy; Poole, David L.; Mackworth, Alan K. (1997) (pdf). *Computational intelligence: A logical approach* (<http://www.cs.ubc.ca/spider/poole/ci/ch1.pdf>). Oxford [Oxfordshire]: Oxford University Press. pp. 1. ISBN 0195102703. .



[47] Canny, John; Russell, Stuart J.; Norvig, Peter (2003). *Artificial intelligence: A modern approach*. Englewood Cliffs, N.J.: Prentice Hall. ISBN 0137903952. OCLC 51325314 60211434 61259102.

## Further reading

- Binet, Alfred; Simon, Th. (1916). *The development of intelligence in children: The Binet-Simon Scale* ([http://books.google.com/?id=jEQSAAAAYAAJ&dq=The development of intelligence in children Binet&pg=PA1#v=onepage&q](http://books.google.com/?id=jEQSAAAAYAAJ&dq=The+development+of+intelligence+in+children+Binet+pg=PA1#v=onepage&q)). Publications of the Training School at Vineland New Jersey Department of Research No. 11. E.S. Kite (Trans.). Baltimore: Williams & Wilkins. Retrieved 18 July 2010.
- Terman, Lewis M. (1916). *The Measurement of Intelligence* (<http://www.gutenberg.org/etext/20662>). Boston: Houghton Mifflin. ISBN 0405064802. Retrieved 26 June 2010.
- Wake, Warren K.; Gardner, Howard; Kornhaber, Mindy L. (1996). *Intelligence: Multiple perspectives*. Fort Worth, TX: Harcourt Brace College Publishers. ISBN 0030726298. OCLC 34414874.
- Khalfa, Jean, ed (1996). *What Is Intelligence?*. Darwin College Lectures. Cambridge: Cambridge University Press. ISBN 9780521566858. Lay summary (<https://www.cambridge.org/us/catalogue/catalogue.asp?isbn=9780521566858>) (4 July 2010).
- Sternberg, Robert J., ed (2000). *Handbook of Intelligence*. Cambridge: Cambridge University Press. ISBN 9780521596480. Lay summary (<http://www.cambridge.org/us/catalogue/catalogue.asp?isbn=9780521596480>) (29 June 2010).
- Richardson, Ken (2000). *The Making of Intelligence*. New York (NY): Columbia University Press. ISBN 978-0-231-12005-0. Lay summary (<http://cup.columbia.edu/book/978-0-231-12004-3/the-making-of-intelligence>) (28 June 2010).
- Bock, Gregory; Goode, Jamie; Webb, Kate, eds (2000). *The Nature of Intelligence* (<http://www3.interscience.wiley.com/cgi-bin/bookhome/118964607?CRETRY=1&SRETRY=0>). Novartis Foundation Symposium 233. Chichester: Wiley. doi:10.1002/0470870850. ISBN 978-0471494348. Retrieved 16 July 2010.
- Blakeslee, Sandra; Hawkins, Jeff (2004). *On intelligence*. New York: Times Books. ISBN 0-8050-7456-2. OCLC 55510125.
- Sternberg, Robert J., ed (2004). *International Handbook of Intelligence*. Cambridge: Cambridge University Press. ISBN 9780521004022. Lay summary (<http://www.cup.es/uk/catalogue/catalogue.asp?isbn=9780521004022>) (29 June 2010).
- Flynn, James R. (2009). *What Is Intelligence: Beyond the Flynn Effect* (expanded paperback ed.). Cambridge: Cambridge University Press. ISBN 978-0-521-74147-7. Lay summary (<http://www.cscs.umich.edu/~crshalizi/reviews/flynn-beyond/>) (18 July 2010).
- Stanovich, Keith (2009). *What Intelligence Tests Miss: The Psychology of Rational Thought*. New Haven (CT): Yale University Press. ISBN 9780300123852. Lay summary (<http://yalepress.yale.edu/yupbooks/book.asp?isbn=9780300123852>) (9 August 2010).
- Garlick, Dennis (2010). *Intelligence and the Brain: Solving the Mystery of Why People Differ in IQ and How a Child Can Be a Genius*. Burbank (CA): Aesop Press. ISBN 9780615319216. Lay summary (<http://www.intelligenceandthebrain.com>) (23 August 2010).

## External links

- Intelligence (<http://www.bbc.co.uk/programmes/p0054513>) on In Our Time at the BBC. ( listen now ([http://www.bbc.co.uk/iplayer/console/p0054513/In\\_Our\\_Time\\_Intelligence](http://www.bbc.co.uk/iplayer/console/p0054513/In_Our_Time_Intelligence)))
- APA Task Force Examines the Knowns and Unknowns of Intelligence (<http://web.archive.org/web/20041130090438/http://www.apa.org/releases/intell.html>) - *American Psychological Association*, Press release
- The cognitive-psychology approach vs. psychometric approach to intelligence (<http://www.americanscientist.org/template/AssetDetail/assetid/24538/page/1>) - *American Scientist* magazine
- History of Influences in the Development of Intelligence Theory and Testing (<http://www.indiana.edu/~intell/map.shtml>) - Developed by Jonathan Plucker at Indiana University

## Scholarly journals and societies

- *Intelligence* ( journal homepage (<http://www.elsevier.com/locate/intell>))
- International Society for Intelligence Research ( homepage (<http://www.isironline.org/>))

# Convergent thinking

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**Convergent thinking** is a term coined by Joy Paul Guilford as the opposite of divergent thinking. It generally means the ability to give the "correct" answer to standard questions that do not require significant creativity, for instance in most tasks in school and on standardized multiple-choice tests for intelligence.

## References

- Peter Salovey, Marc A. Brackett, John D. Mayer (2004). *Emotional Intelligence: Key Readings on the Mayer and Salovey Model*. NPR Inc.. p. 171. ISBN 1887943722.
- Convergent Thinking at the Encyclopedia of Psychology <sup>[1]</sup>

## References

- [1] <http://www.enotes.com/gale-psychology-encyclopedia/convergent-thinking>
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# Divergent thinking

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**Divergent thinking** is a thought process or method used to generate creative ideas by exploring many possible solutions. It is often used in conjunction with convergent thinking, which follows a particular set of logical steps to arrive at one solution, which in some cases is a "correct" solution. Divergent thinking typically occurs in a spontaneous, free-flowing manner, such that many ideas are generated in an unorganized fashion. Many possible solutions are explored in a short amount of time, and unexpected connections are drawn. After the process of divergent thinking has been completed, ideas and information are organized and structured using convergent thinking.<sup>[1]</sup>

Psychologists have found that a high IQ alone does not guarantee creativity. Instead, personality traits that promote divergent thinking are more important. Divergent thinking is found among people with personalities which have traits such as nonconformity, curiosity, willingness to take risks, and persistence.<sup>[2]</sup> Additionally, researchers at Vanderbilt University found that musicians are more adept at utilizing both hemispheres and more likely to use divergent thinking in their thought processes.<sup>[3]</sup>

Activities which promote divergent thinking include creating lists of questions, setting aside time for thinking and meditation, brainstorming, subject mapping / "bubble mapping", keeping a journal, creating artwork, and free writing.<sup>[1]</sup> In free writing, a person will focus on one particular topic and write non-stop about it for a short period of time, in a stream of consciousness fashion.<sup>[1]</sup>

## References

- [1] "Strategies of Divergent Thinking" (<http://faculty.washington.edu/ezent/imdt.htm>). University of Washington. . Retrieved 2009-08-06.
- [2] Wade, Carole; Tavis, Carol (2008). *Invitation to Psychology*. Upper Saddle River, NJ: Pearson - Prentice Hall. pp. 258. ISBN 0-13-601609.
- [3] "Musicians use both sides of their brains more frequently than average people" (<http://www.physorg.com/news142185056.html>). PhysOrg.com. 2008-10-02. . Retrieved 2009-08-06.

## External links

- "Changing (Education) Paradigms" ([http://www.youtube.com/watch?v=zDZFcDGpL4U&feature=player\\_embedded](http://www.youtube.com/watch?v=zDZFcDGpL4U&feature=player_embedded)) by Sir Ken Robinson - video animation by the *Royal Society of Arts*

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# J. P. Guilford

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**Joy Paul Guilford** (March 7, 1897, Marquette, Nebraska – November 26, 1987, Los Angeles) was a US psychologist, best remembered for his psychometric study of human intelligence, including the important distinction between convergent and divergent production.

Developing the views of L. L. Thurstone, Guilford rejected Charles Spearman's view that intelligence could be characterized in a single numerical parameter and proposed that three dimensions were necessary for accurate description: content, operations, and productions.

## Guilford's career

Guilford graduated from the University of Nebraska before studying under Edward Titchener at Cornell. In 1938 Guilford became the 3rd President of the Psychometric Society, following in the footsteps of its founder Louis Leon Thurstone and of EL Thorndike who held the position in 1937. Guilford held a number of posts at Nebraska and briefly at the University of Southern California. In 1941 he entered the U.S. Army as a Lieutenant Colonel and served as Director of Psychological Research Unit No. 3 at Santa Ana Army Air Base. There he worked on the selection and ranking of aircrew trainees as the Army Air Force investigated why a sizable proportion of trainees was not graduating.

Promoted to Chief of the Psychological Research Unit at the U.S. Army Air Forces Training Command Headquarters in Fort Worth, Guilford oversaw the "Stanines Project," which identified eight specific intellectual abilities crucial to flying a plane. (*Stanines*, now a common term in educational psychology, was coined during Guilford's project). Over the course of World War II, Guilford's use of these eight factors in the development of the two-day Classification Test Battery was significant in increasing graduation rates for aircrew trainees.

Discharged as a full Colonel after the War, Guilford joined the Education faculty at the University of Southern California and continued to research the factors of intelligence. He published widely on what he ultimately named the Structure of Intellect theory, and his post-War research identified a total of 90 discrete intellectual abilities and 30 behavioral abilities.

Guilford's 20 years of research at Southern California were funded by the National Science Foundation, the Office of Education of the former Health, Education and Welfare Department, and the Office of Naval Research. Although Guilford's subjects were recruits at the Air Force Training Command at Randolph Air Force Base, San Antonio, the Office of Naval Research managed this research.

Guilford's post-War research led to the development of classification testing that, modified in different ways, entered into the various personnel assessments administered by all branches of the U.S. Armed Services. Thus, in a generic manner, all U.S. Military qualifying exams of the 1950s, 1960s, and 1970s may be said to have descended from Guilford's research.

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## Guilford's Structure of Intellect

According to Guilford's Structure of Intellect (SI) theory, an individual's performance on intelligence tests can be traced back to the underlying mental abilities or factors of intelligence. SI theory comprises up to 150 different intellectual abilities organized along three dimensions—Operations, Content, and Products.

### Operations dimension

SI includes six operations or general intellectual processes:

Cognition—The ability to understand, comprehend, discover, and become aware of information.

Memory recording—The ability to encode information.

Memory retention—The ability to recall information.

Divergent production—The ability to generate multiple solutions to a problem; creativity.

Convergent production—The ability to deduce a single solution to a problem; rule-following or problem-solving.

Evaluation—The ability to judge whether or not information is accurate, consistent, or valid.

### Content dimension

SI includes five broad areas of information to which the human intellect applies the six operations:

Visual—Information perceived through seeing.

Auditory—Information perceived through hearing.

Kinesthetic—Information perceived through one's own physical actions.

Symbolic—Information perceived as symbols or signs that have no meaning by themselves; e.g., Arabic numerals or the letters of an alphabet.

Semantic—Which is concerned with verbal meaning and ideas.

Behavioral—Information perceived as acts of people.

### Product dimension

As the name suggests, this dimension contains results of applying particular operations to specific contents. The SI model includes six products, in increasing complexity:

Units—Single items of knowledge.

Classes—Sets of units sharing common attributes.

Relations—Units linked as opposites or in associations, sequences, or analogies.

Systems—Multiple relations interrelated to comprise structures or networks.

Transformations—Changes, perspectives, conversions, or mutations to knowledge.

Implications—Predictions, inferences, consequences, or anticipations of knowledge.

Therefore, according to Guilford there are  $6 \times 5 \times 6 = 180$  intellectual abilities or factors. Each ability stands for a particular operation in a particular content area and results in a specific product, such as Comprehension of Figural Units or Evaluation of Semantic Implications.

Guilford's original model was composed of 120 components because he had not separated Figural Content into separate Auditory and Visual contents, nor had he separated Memory into Memory Recording and Memory Retention. When he separated Figural into Auditory and Visual contents, his model increased to  $5 \times 5 \times 6 = 150$  categories. When Guilford separated the Memory functions, his model finally increased to the final 180 factors [Guilford, J.P. (1988). Some changes in the structure of intellect model. *Educational and Psychological Measurement*, 48, 1-4.]

## Criticism

Guilford's approach is rejected by intelligence researchers who support the existence of a general factor of mental ability. For example, according to Jensen (1998), Guilford's contention that a *g*-factor was untenable was probably influenced by his observation that a considerable number of cognitive tests of U.S. Air Force personnel did not show correlations that were significantly different from zero. However, Jensen states that according to later reanalyses, this resulted from artifacts such as sampling errors, restriction of range, and measurement errors. With proper corrections for these artifacts, all of the correlations in Guilford's data sets are positive.<sup>[1]</sup>

Several researchers have criticized the statistical techniques used by Guilford. In one analysis, which used Guilford's own data and factorial procedures, randomly generated factorial theories were found to be as well supported as his own theory.<sup>[2]</sup>

Guilford's Structure-of-Intellect model of human abilities has few supporters today. Carroll (1993) summarized the view of later researchers:<sup>[3]</sup>

"Guilford's SOI model must, therefore, be marked down as a somewhat eccentric aberration in the history of intelligence models; that so much attention has been paid to it is disturbing, to the extent that textbooks and other treatments of it have given the impression that the model is valid and widely accepted, when clearly it is not."

## Selected bibliography

- Guilford, J.P. (1950) Creativity, *American Psychologist*, Volume 5, Issue 9, 444–454.
- Guilford, J.P. (1967). *The Nature of Human Intelligence*.
- Guilford, J.P. & Hoepfner, R. (1971). *The Analysis of Intelligence*.
- Guilford, J.P. (1982). Cognitive psychology's ambiguities: Some suggested remedies. *Psychological Review*, 89, 48–59.

## Notes

[1] Jensen 1998, 115–117.

[2] Mackintosh 1998, 214–215.

[3] Carroll 1993, 60. For a more detailed critique of the Structure-of-Intellect model, see 57–60.

## References

- Carroll, J. B. (1993). *Human Cognitive Abilities*. Cambridge, UK: Cambridge University Press.
- Jensen, A. R. (1998). *The g Factor: The Science of Mental Ability*. Westport, CT: Praeger.
- Mackintosh, N. J. (1998). *IQ and Human Intelligence*. Oxford, UK: Oxford University Press.

## External links

- The structure of intellect (<http://tip.psychology.org/guilford.html>)

# Robert Sternberg

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<b>Robert Jeffrey Sternberg</b>	
<b>Born</b>	December 8, 1949Newark, New Jersey, U.S.
<b>Nationality</b>	American
<b>Fields</b>	psychometrician
<b>Institutions</b>	Oklahoma State University, Yale University, Tufts University
<b>Alma mater</b>	Yale University, Stanford University
<b>Doctoral advisor</b>	Gordon Bower
<b>Known for</b>	Triarchic theory of intelligence, Triangular theory of love

**Robert Jeffrey Sternberg** (born December 8, 1949), is an American psychologist and psychometrician and Provost at Oklahoma State University. He was formerly the Dean of Arts and Sciences at Tufts University, IBM Professor of Psychology and Education at Yale University and the President of the American Psychological Association. He is a member of the editorial boards of numerous journals, including *American Psychologist*. Sternberg has a BA from Yale University and a PhD from Stanford University. Gordon Bower was his PhD advisor. He holds ten honorary doctorates from one North American, one South American, and eight European universities, and additionally holds an honorary professorate at the University of Heidelberg in Germany. He is currently also a Distinguished Associate of The Psychometrics Centre at the University of Cambridge.

## Research interests

Sternberg's main research include the following interests:

- Higher mental functions, including intelligence and creativity
- Styles of thinking
- Cognitive modifiability
- Leadership
- Love and hate
- Love and war

Sternberg has proposed a triarchic theory of intelligence and a triangular theory of love. He is the creator (with Todd Lubart<sup>[1]</sup>) of the investment theory of creativity, which states that creative people buy low and sell high in the world of ideas, and a propulsion theory of creative contributions, which states that creativity is a form of leadership.

He is spearheading an experimental admissions process at Tufts to quantifiably test the creativity of an applicant.<sup>[2]</sup>

Sternberg has criticized IQ tests, saying they are "convenient partial operationalizations of the construct of intelligence, and nothing more. They do not provide the kind of measurement of intelligence that tape measures provide of height."<sup>[3]</sup>

In 1995, he was on an American Psychological Association task force writing a consensus statement on the state of intelligence research in response to the claims being advanced amid the *Bell Curve* controversy, titled "Intelligence: Knowns and Unknowns."

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## A theory of intelligence

Many descriptions of intelligence focus on mental abilities such as vocabulary, comprehension, memory and problem-solving that can be measured through intelligence tests. This reflects the tendency of psychologists to develop their understanding of intelligence by observing behaviour believed to be associated with intelligence.

Sternberg believes that this focus on specific types of measurable mental abilities is too narrow. He believes that studying intelligence in this way leads to an understanding of only one part of intelligence and that this part is only seen in people who are "school smart" or "book smart".

There are, for example, many individuals who score poorly on intelligence tests, but are creative or are "street smart" and therefore have a very good ability to adapt and shape their environment. According to Sternberg (2003), giftedness should be examined in a broader way incorporating other parts of intelligence.

## The Triarchic Model

Sternberg (2003) categorizes intelligence into three parts, which are central in his theory, the triarchic theory of intelligence:

- Analytical intelligence, the ability to complete academic, problem-solving tasks, such as those used in traditional intelligence tests. These types of tasks usually present well-defined problems that have only a single correct answer.
- Creative or synthetic intelligence, the ability to successfully deal with new and unusual situations by drawing on existing knowledge and skills. Individuals high in creative intelligence may give 'wrong' answers because they see things from a different perspective.
- Practical intelligence, the ability to adapt to everyday life by drawing on existing knowledge and skills. Practical intelligence enables an individual to understand what needs to be done in a specific setting and then do it.

Sternberg (2003) discusses experience and its role in intelligence. Creative or synthetic intelligence helps individuals to transfer information from one problem to another. Sternberg calls the application of ideas from one problem to a new type of problem *relative novelty*. In contrast to the skills of relative novelty there is *relative familiarity* which enables an individual to become so familiar with a process that it becomes automatized. This can free up brain resources for coping with new ideas.

Context, or how one adapts, selects and shapes their environment is another area that is not represented by traditional measures of giftedness. Practically intelligent people are good at picking up tacit information and utilizing that information. They tend to shape their environment around them. (Sternberg, 2003)

Sternberg (2003) developed a testing instrument to identify people who are gifted in ways that other tests don't identify. The Sternberg Triarchic Abilities Test measures not only traditional intelligence abilities but analytic, synthetic, automatization and practical abilities as well. There are four ways in which this test is different from conventional intelligence tests.

- This test is broader, measuring synthetic and practical skills in addition to analytic skills. The test provides scores on analytic, synthetic, automatization, and practical abilities, as well as verbal, quantitative, and figural processing abilities.
- The test measures the ability to understand unknown words in context rather than vocabulary skills which are dependent on an individual's background.
- The automatization subtest is the only part of the test that measures mental speed.
- The test is based on a theory of intelligence.

[4]



### Practical application

Sternberg added experimental criteria to the application process for undergraduates to Tufts University, where he was Dean of Arts and Sciences, to test "creativity and other non-academic factors." Calling it the "first major university to try such a departure from the norm," *Inside Higher Ed* noted that Tufts continues to consider the SAT and other traditional criteria.<sup>[5] [6]</sup>

### Theory in cognitive styles

Sternberg proposed a theory of cognitive styles in 1997.

Sternberg's basic idea is that the forms of government we have in the world are external reflections of the way different people view and act in the world, that is, different ways of organizing and thinking. Cognitive styles should not be confused with abilities, they are the way we prefer to use these abilities. Indeed a good fit between a person's preferred cognitive profile and his abilities can create a powerful synergy that outweighs the sum of its parts.

The main three branches of government are the executive branch, legislative branch and judicial branch. People also need to perform these functions in their own thinking and working. Legislative people like to build new structures, creating their own rules along the way. Executive people are rule followers, they like to be given a predetermined structure in which to work in. Judicial people like to evaluate rules and procedures, to analyze a given structure.

The four forms of mental self-government are hierarchical, monarchic, oligarchic, and anarchic. The hierarchic style holds multiple goals simultaneously and prioritizes them. The oligarchic style is similar but differs in involving difficulty prioritizing. The monarchic style, in comparison, focuses on a single activity until completion. The anarchic style resists conformity to "systems, rules, or particular approaches to problems."

The two levels of mental self-government are local and global. The local style focuses on more specific and concrete problems, in extreme case they "can't see the forest for the trees". The global style, in comparison, focuses on more abstract and global problems, in extreme cases they "can't see the trees for the forest".

The two scopes of mental self-government are internal and external. The internal style focuses inwards and prefers to work independently. The external style focuses outwards and prefers to work in collaboration.

The two leanings of mental self-government are the liberal and conservative. These styles have nothing to do with politics. The liberal individual likes change, to go beyond exciting rules and procedures. The conservative individual dislikes change and ambiguity, he will be happiest in a familiar and predictable environment.

We all have different profiles of thinking styles which can change over situations and time of life. Moreover a person can, and often does, have a secondary preferred thinking style.

### Bibliography

#### Key References

On "*Higher Mental Functions*":

- Sternberg, R. J. (1977): *Intelligence, information processing, and analogical reasoning: The componential analysis of human abilities*. Hillsdale, NJ: Erlbaum.
- Sternberg, R. J. (1985): *Beyond IQ: A triarchic theory of human intelligence*. New York: Cambridge University Press.
- Sternberg, R. J. (1990): *Metaphors of mind: Conceptions of the nature of intelligence*. New York: Cambridge University Press.
- Sternberg, R. J. (1997): *Successful intelligence*. New York: Plume.
- Sternberg, R. J. (1999): "The theory of successful intelligence." *Review of General Psychology*, 3, 292-316.
- Sternberg, R. J., Forsythe, G. B., Hedlund, J., Horvath, J., Snook, S., Williams, W. M., Wagner, R. K., & Grigorenko, E. L. (2000): *Practical intelligence in everyday life*. New York: Cambridge University Press.

- Sternberg, R. J., & Grigorenko, E. L. (2000): *Teaching for successful intelligence*. Arlington Heights, IL: Skylight.
- (2007) Sternberg, R.J.: *Wisdom, Intelligence, and Creativity Synthesized*. New York: Cambridge University Press

#### Key References

On "*Creativity*":

- Sternberg, R. J., James C Kaufman, & Pretz, J. E. (2002): *The creativity conundrum: A propulsion model of creative contributions*. Philadelphia, PA.
- Sternberg, R. J., & Lubart, T. I. (1995): *Defying the crowd: Cultivating creativity in a culture of conformity*. New York: Free Press.
- Sternberg, R. J., & Williams, W. M. (1996): *How to develop student creativity*. Alexandria, VA: Association for Supervision and Curriculum Development.

#### Key Reference

On "*Leadership*":

Sternberg, R. J., & Vroom, V. H. (2002): "The person versus the situation in leadership." *Leadership Quarterly*, 13, 301-323

#### Key Reference

On "*Cognitive Styles*":

Sternberg, R. & Grigorenko, E. (1997). Are cognitive styles still in style? *American Psychologist*, 52, 700-712.

## References

- [1] Sternberg, R. J., & Lubart, T. I. (1995). *Defying the crowd: Cultivating creativity in a culture of conformity*. New York: Free Press.
- [2] Jaschik, Scott (2006). A "Rainbow" Approach to Admissions (<http://www.insidehighered.com/news/2006/07/06/tufts>). Inside Higher Ed, July 6, 2006.
- [3] The Theory of Successful Intelligence (<http://www.psicorip.org/IJPNew/Resumos/PerP/RIP/RIP036a0/RIP03921.pdf>) Interamerican Journal of Psychology - 2005, Vol. 39, Num. 2 pp. 189-20
- [4] Sternberg, R. J. (2003). Giftedness According to the Theory of Successful Intelligence. In N. Colangelo & G. Davis (Eds.), *Handbook of Gifted Education* (88-99). Boston MA: Allyn and Bacon.
- [5] Jaschik, Scott (2006). A "Rainbow" Approach to Admissions (<http://www.insidehighered.com/news/2006/07/06/tufts>). Inside Higher Ed, July 6, 2006.
- [6] McAnerny, Kelly (2005). From Sternberg, a new take on what makes kids Tufts-worthy (<http://www.tuftsdaily.com/media/storage/paper856/news/2005/11/15/News/From-Sternberg.A.New.Take.On.What.Makes.Kids.TuftsWorthy-1492093.shtml?nrewrite=200607062142&sourcedomain=www.tuftsdaily.com>). Tufts Daily, November 15, 2005.

## External links

- Robert J. Sternberg. A page dedicated to his life's work. (<http://academics.tjhsst.edu/psych/oldPsych/sternberg/>)
- Robert J. Sternberg - Dean of the School of Arts and Sciences - Tufts University ([http://provost.tufts.edu/1174149600661/Provost-Page-prov2w\\_1174149600774.html](http://provost.tufts.edu/1174149600661/Provost-Page-prov2w_1174149600774.html)) (Tufts profile)
- Biographical sketch (<http://www.psychometrics.cam.ac.uk/page/68/bob-sternberg.htm>), The Psychometrics Centre
- (<http://www.cam.ac.uk/>), University of Cambridge
- Triarchic Theory of Intelligence - uwsp.edu (<http://www.uwsp.edu/education/lwilson/learning/sternb1.htm>)
- Video (with mp3 available) of discussion about intelligence and creativity with Sternberg (<http://bloggingheads.tv/diavlogs/21276>) on Bloggingheads.tv

## Further reading

- Gardner, Howard. *Frames of Mind: The Theory of Multiple Intelligences*. New York: Basic, 1983

# Triarchic theory of intelligence

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The **triarchic theory of intelligence** was formulated by Robert J. Sternberg, a prominent figure in the research of human intelligence. The theory by itself was groundbreaking in that it was among the first to go against the psychometric approach to intelligence and take a more cognitive approach.

Sternberg's definition of human intelligence is "(a) *mental activity directed toward purposive adaptation to, selection and shaping of, real-world environments relevant to one's life*" (Sternberg, 1985, p. 45), which means that intelligence is how well an individual deals with environmental changes throughout their lifespan. Sternberg's theory comprises three parts: componential, experiential, and practical.

## Different components of information processing

Sternberg associated the workings of the mind with a series of components. These components he labeled the metacomponents, performance components, and knowledge-acquisition components (Sternberg, 1985).

The *metacomponents* are executive processes used in problem solving and decision making that involve the majority of managing our mind. They tell the mind how to act. Metacomponents are also sometimes referred to as a homunculus. A homunculus is a fictitious or metaphorical "person" inside our head that controls our actions, and which is often seen to invite an infinite regress of homunculi controlling each other (Sternberg, 1985).

Sternberg's next set of components, *performance components*, are the processes that actually carry out the actions the metacomponents dictate. These are the basic processes that allow us to do tasks, such as perceiving problems in our long-term memory, perceiving relations between objects, and applying relations to another set of terms (Sternberg, 1997).

The last set of components, *knowledge-acquisition components*, are used in obtaining new information. These components complete tasks that involve selectively choosing information from irrelevant information. These components can also be used to selectively combine the various pieces of information they have gathered. Gifted individuals are proficient in using these components because they are able to learn new information at a greater rate (Sternberg, 1997).

Whereas Sternberg explains that the basic information processing components underlying the three parts of his triarchic theory are the same, different contexts and different tasks require different kind of intelligence (Sternberg, 2001).

## Componential / Analytical Subtheory

Sternberg associated the componential subtheory with analytical giftedness. This is one of three types of giftedness that Sternberg recognizes. Analytical giftedness is influential in being able to take apart problems and being able to see solutions not often seen. Unfortunately, individuals with only this type are not as adept at creating unique ideas of their own. This form of giftedness is the type that is tested most often.

Other areas deal with creativity and other abilities not easily tested. Sternberg gave the example of a student, "Alice", who had excellent test scores and grades, and teachers viewed her as extremely smart. Alice was later seen having trouble in graduate school because she was not adept at creating ideas of her own (Sternberg, 1997). ..

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## Experiential / Creative Subtheory

Sternberg's 2nd stage of his theory is his experiential subtheory. This stage deals mainly with how well a task is performed with regard to how familiar it is. Sternberg splits the role of experience into two parts: novelty and automation.

A *novel* situation is one that you have never experienced before. People that are adept at managing a novel situation can take the task and find new ways of solving it that the majority of people would not notice (Sternberg, 1997).

A process that has been *automated* has been performed multiple times and can now be done with little or no extra thought. Once a process is automatized, it can be run in parallel with the same or other processes. The problem with novelty and automation is that being skilled in one component does not ensure that you are skilled in the other (Sternberg, 1997).

The experiential subtheory also correlates with another one of Sternberg's proposed types of giftedness. Synthetic giftedness is seen in creativity, intuition, and a study of the arts. People with synthetic giftedness are not often seen with the highest IQ's because there are not currently any tests that can sufficiently measure these attributes, but synthetic giftedness is especially useful in creating new ideas to create and solve new problems. Sternberg also associated another one of his students, "Barbara", to the synthetic giftedness. Barbara did not perform as well as Alice on the tests taken to get into school, but was recommended to Yale University based on her exceptional creative and intuitive skills. Barbara was later very valuable in creating new ideas for research (Sternberg, 1997).

## Practical / Contextual Subtheory

Sternberg's third subtheory of intelligence, called practical or contextual, "deals with the mental activity involved in attaining fit to context" (Sternberg, 1985, p.45). Through the three processes of adaptation, shaping, and selection, individuals create an ideal fit between themselves and their environment. This type of intelligence is often referred to as "street smarts."

*Adaptation* occurs when one makes a change within oneself in order to better adjust to one's surroundings (Sternberg, 1985). For example, when the weather changes and temperatures drop, people adapt by wearing extra layers of clothing to remain warm.

*Shaping* occurs when one changes their environment to better suit one's needs (Sternberg, 1985). A teacher may invoke the new rule of raising hands to speak to ensure that the lesson is taught with least possible disruption.

The process of *selection* is undertaken when a completely new alternate environment is found to replace the previous, unsatisfying environment to meet the individual's goals (Sternberg, 1985). For instance, immigrants leave their lives in their homeland countries where they endure economical and social hardships and go to other countries in search of a better and less strained life.

The effectiveness with which an individual fits to his or her environment and contends with daily situations reflects degree of intelligence. Sternberg's third type of giftedness, called practical giftedness, involves the ability to apply synthetic and analytic skills to everyday situations. Practically gifted people are superb in their ability to succeed in any setting (Sternberg, 1997). An example of this type of giftedness is "Celia". Celia did not have outstanding analytical or synthetic abilities, but she "was highly successful in figuring out what she needed to do in order to succeed in an academic environment. She knew what kind of research was valued, how to get articles into journals, how to impress people at job interviews, and the like" (Sternberg, 1997, p.44). Celia's contextual intelligence allowed her to use these skills to her best advantage.

Sternberg also acknowledges that an individual is not restricted to having excellence in only one of these three intelligences. Many people may possess an integration of all three and have high levels of all three intelligences.

## Challenges

Psychologist Linda Gottfredson (Gottfredson, 2003) criticises the unempirical nature of triarchic theory and argues that it is absurd to assert that traditional Intelligence tests are not measuring practical intelligence when they show a moderate correlation with income, especially at middle age when individuals have had a chance to reach their maximum career potential, an even higher correlation with occupational prestige, and that IQ tests even predict the ability to stay out of jail and stay alive (all of which qualifies as practical intelligence or "street smarts").

Gottfredson claims that what Sternberg calls practical intelligence is not a broad aspect of cognition at all but simply a specific set of skills people learn to cope with a specific environment (task specific knowledge).

As for the creative component of Sternberg's model, a Harvard study questions whether it is meaningful to treat creativity as a cognitive ability separate from analytical intelligence, but instead finds that creativity is simply the product of a high intelligence score combined with a low level of latent inhibition—when high intelligence levels are not present, low levels of latent inhibition put one especially at risk for schizophrenia.<sup>[1]</sup>

## References

[1] Decreased Latent Inhibition Is Associated With Increased Creative Achievement in High-Functioning Individuals (<http://www.nidsci.org/pdf/carson-peterson-higgins.pdf>)

## Bibliography

- Gottfredson, L. (2003). Dissecting practical intelligence theory: Its claims and its evidence. *Intelligence*, 31, 343-397.
- Sternberg, R. J. (1985). *Beyond IQ: A Triarchic Theory of Intelligence*. Cambridge: Cambridge University Press.
- Sternberg, R. J. (1997). A Triarchic View of Giftedness: Theory and Practice. In N. Coleangelo & G. A. Davis (Eds.), *Handbook of Gifted Education* (pp. 43-53). Boston, MA: Allyn and Bacon.
- Sternberg, R.J., Nokes, C., Geissler, W., Prince, P., Okatcha, F., Bundy, D.A., Grigorenke, E.L. (2001). The relationship between academic and practical intelligence: a case study in Kenya. *Intelligence*, 29, 401-418.

# Creativity

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**Creativity** refers to the phenomenon whereby a person creates something new (a product, a solution, a work of art etc.) that has some kind of value. What counts as "new" may be in reference to the individual creator, or to the society or domain within which the novelty occurs. What counts as "valuable" is similarly defined in a variety of ways.

Scholarly interest in creativity ranges widely: the relationship between creativity and general intelligence; the mental and neurological processes associated with creative activity; personality type and creative ability; creativity and mental health; creativity in education; and ways of fostering creativity through training and technology.

Creativity and creative acts are therefore studied across several disciplines - psychology, cognitive science, education, philosophy (particularly philosophy of science), technology, theology, sociology, linguistics, business studies, and economics. As a result, there are a multitude of definitions and approaches.

## Etymology

The lexeme in the English word *creativity* comes from the Latin term *creō* "to create, make" and its derivational suffixes also come from Latin. The word "create" appears in English as early as the 14th century, notably in Chaucer<sup>[1]</sup> (in *The Parson's Tale*<sup>[2]</sup>). However, its modern meaning as an act of human creation did not emerge until after the Enlightenment.<sup>[1]</sup>

## Definition

In a summary of scientific research into creativity Michael Mumford suggested: "Over the course of the last decade, however, we seem to have reached a general agreement that creativity involves the production of novel, useful products" (Mumford, 2003, p. 110).<sup>[3]</sup> Beyond this general commonality, authors have diverged dramatically in their precise definitions, with Peter Meusburger claiming that over a hundred different versions can be found in the literature.<sup>[4]</sup>

## Aspects of creativity

Theories of creativity (in particular investigating why some people are more creative than others) have focused on a variety of aspects. The most dominant are usually identified as the four "Ps" - process, product, person and place.<sup>[5]</sup> A focus on *process* is shown in cognitive approaches that try to describe thought mechanisms and techniques for creative thinking. Theories invoking divergent rather than convergent thinking (such as Guilford), or those describing the staging of the creative process (such as Wallas) are primarily theories of creative process. A focus on creative *product* usually appears in attempts to measure creativity in people (psychometrics, see below), or in creative ideas framed as successful memes.<sup>[6]</sup> A focus on the nature of the creative *person* considers more general intellectual habits, such as openness, levels of ideation, autonomy, expertise, exploratory behaviour and so on. A focus on *place* considers the best circumstances in which creativity flourishes, including degrees of autonomy, access to resources and the nature of gatekeepers.

## Historical and personal creativity

The product of "creativity" has typically been defined in one of two ways: either as something historically new (and relatively rare), such as scientific discoveries or great works of art; or as producing something new in a personal sense - an apparent innovation for the creator, regardless of whether others have made similar innovations, or whether others value the particular act of creation. In the former sense there are writers such as Mihály Csíkszentmihályi<sup>[7]</sup> have defined creativity in terms of rare individuals who have been judged by others to have made significant creative, often domain-changing contributions (and as such, the level of creativity of an individual

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can vary over historical time as perceptions change), and Simonton, who has analysed the career trajectories of the creatively eminent in order to map patterns and predictors of creative productivity.<sup>[8]</sup> In the latter sense, writers such as Ken Robinson,<sup>[9]</sup> and Anna Craft<sup>[10]</sup> have focussed on creativity in a general population, particularly with respect to education.

There are a variety of labels for the two sides of this dichotomy. Margaret Boden distinguishes between h-creativity (historical) and p-creativity (personal).<sup>[11]</sup> Craft makes a similar distinction between "high" and "little c" creativity.<sup>[10]</sup> while Craft cites Robinson referring to "high" and "democratic" creativity. Common also is the pairing of terms "Big C" and "Little C".

Kozbelt, Beghetto and Runco, use a little-c/Big-C model to review major theories of creativity.<sup>[5]</sup> This approach was first introduced by James C. Kaufman and Beghetto into a four C model: *mini-c* (transformative learning), which are "personally meaningful interpretations of experiences, actions and insights"; *little-c* (everyday problem solving and creative expression); *Pro-C*, exhibited by people who are professionally or vocationally creative but not eminent, and *Big-C*, reserved for those who are considered truly great in their field. This was to help distinguish more clearly between the amateur unapprenticed in the particular creative domain (e.g. the visual arts, astrophysics etc.), the professional who was domain-competent, and creative genius. The four-c model was also intended to help accommodate models and theories of creativity that stressed domain-competence as an essential component, and domain transformation as the highest mark of creativity; it also, they argued, made a useful framework for analysing creative processes in individuals.<sup>[12]</sup>

## History of the term and the concept

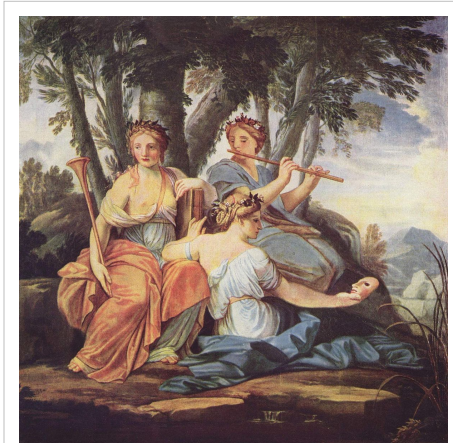
### Traditional views in the West and East

It is generally thought that "creativity" in Western culture was originally seen as a matter of divine inspiration.<sup>[1]</sup> In Greek culture, for instance, Muses were seen as mediating inspiration from the Gods.<sup>[13]</sup> Romans and Greeks invoked the concept of an external creative "daemon" (Greek) or "genius" (Latin), linked to the sacred or the divine. This probably came closest to describing what the modern age views as creative talent.<sup>[14]</sup> In the Judaeo-Christian tradition, creativity was the sole province of God; humans were not considered to have the ability to create something new except as an expression of God's work.<sup>[15]</sup>

The traditional Western view of creativity can be contrasted with the traditional Eastern view. For Hindus, Confucianists, Taoists and Buddhists, creation was at most a kind of discovery or mimicry, and the idea of creation "from nothing" had no place in these philosophies and religions.<sup>[14]</sup>

### The Enlightenment and after

In the West, this view of creativity as divinely inspired was dominant until the time of the renaissance and even later.<sup>[15]</sup> However, by the 18th century and the Age of Enlightenment, mention of creativity (notably in art theory), linked with the concept of imagination, became more frequent.<sup>[16]</sup> In the writing of Thomas Hobbes, imagination became a key element of human cognition;<sup>[11]</sup> William Duff was one of the first to identify imagination as a quality of genius, typifying the separation being made between talent (productive, but breaking no new ground) and genius.<sup>[13]</sup>



The Muses Clio, Euterpe, and Thalia, by Eustache Le Sueur. Up to the Renaissance, creativity in Western culture was seen as a form of divine inspiration.

As a direct and independent topic of study, creativity effectively received no attention until the 19th century.<sup>[13]</sup> Runco and Albert argue that creativity as the subject of proper study began seriously to emerge in the late 19th century with the increased interest in individual differences inspired by the arrival of Darwinism. In particular they refer to the work of Francis Galton, who through his eugenicist outlook took a keen interest in the heritability of intelligence, with creativity taken as an aspect of genius.<sup>[1]</sup>

In the late 19th and early 20th centuries, leading mathematicians and scientists such as Hermann von Helmholtz (1896) and Henri Poincaré (1908) began to reflect on and publicly discuss their creative processes, and these insights were built on in early accounts of the creative process by pioneering theorists such as Graham Wallas<sup>[17]</sup> and Max Wertheimer.

The formal psychometric measurement of creativity, from the standpoint of orthodox psychological literature, is usually considered to have begun with J. P. Guilford's 1950 address to the American Psychological Association, which helped popularize the topic<sup>[18]</sup> and focus attention on a scientific approach to conceptualizing creativity. (It should be noted that the London School of Psychology had instigated psychometric studies of creativity as early as 1927 with the work of H. L. Hargreaves into the Faculty of Imagination,<sup>[19]</sup> but it did not have the same impact.) Statistical analysis led to the recognition of creativity (as measured) as a separate aspect of human cognition to IQ-type intelligence, into which it had previously been subsumed. Guilford's work suggested that above a threshold level of IQ, the relationship between creativity and classically measured intelligence broke down.<sup>[5]</sup>

## Creativity in psychology and cognitive science

The study of the mental representations and processes underlying creative thought belongs to the domains of psychology and cognitive science.

A psychodynamic approach to understanding creativity was proposed by Sigmund Freud, who suggested that creativity arises as a result of frustrated desires for fame, fortune and love, with the energy that was previously tied up in frustration and emotional tension in the neurosis being sublimated into creative activity. Freud later retracted this view.

### Graham Wallas

Graham Wallas, in his work *Art of Thought*, published in 1926, presented one of the first models of the creative process. In the Wallas stage model, creative insights and illuminations may be explained by a process consisting of 5 stages:

- (i) *preparation* (preparatory work on a problem that focuses the individual's mind on the problem and explores the problem's dimensions),
- (ii) *incubation* (where the problem is internalized into the unconscious mind and nothing appears externally to be happening),
- (iii) *intimation* (the creative person gets a "feeling" that a solution is on its way),
- (iv) *illumination* or insight (where the creative idea bursts forth from its preconscious processing into conscious awareness); and
- (v) *verification* (where the idea is consciously verified, elaborated, and then applied).

In numerous publications, Wallas' model is just treated as four stages, with "intimation" seen as a sub-stage. There has been some empirical research looking at whether, as the concept of "incubation" in Wallas' model implies, a period of interruption or rest from a problem may aid creative problem-solving. Ward<sup>[20]</sup> lists various hypotheses that have been advanced to explain why incubation may aid creative problem-solving, and notes how some empirical evidence is consistent with the hypothesis that incubation aids creative problem-solving in that it enables "forgetting" of misleading clues. Absence of incubation may lead the problem solver to become fixated on inappropriate strategies of solving the problem.<sup>[21]</sup> This work disputes the earlier hypothesis that creative solutions to problems



arise mysteriously from the unconscious mind while the conscious mind is occupied on other tasks.<sup>[22]</sup>

Wallas considered creativity to be a legacy of the evolutionary process, which allowed humans to quickly adapt to rapidly changing environments. Simonton<sup>[23]</sup> provides an updated perspective on this view in his book, *Origins of genius: Darwinian perspectives on creativity*.

### **J. P. Guilford**

Guilford<sup>[24]</sup> performed important work in the field of creativity, drawing a distinction between convergent and divergent production (commonly renamed convergent and divergent thinking). Convergent thinking involves aiming for a single, correct solution to a problem, whereas divergent thinking involves creative generation of multiple answers to a set problem. Divergent thinking is sometimes used as a synonym for creativity in psychology literature. Other researchers have occasionally used the terms *flexible* thinking or fluid intelligence, which are roughly similar to (but not synonymous with) creativity.

### **Arthur Koestler**

In *The Act of Creation*, Arthur Koestler<sup>[25]</sup> lists three types of creative individual - the *Artist*, the *Sage* and the *Jester*. Believers in this trinity hold all three elements necessary in business and can identify them all in "truly creative" companies as well. Koestler introduced the concept of *bisociation*—that creativity arises as a result of the intersection of two quite different frames of reference.

### **Genevieve model**

In 1992, Finke et al. proposed the "Genevieve" model, in which creativity takes place in two phases: a generative phase, where an individual constructs mental representations called preinventive structures, and an exploratory phase where those structures are used to come up with creative ideas. Weisberg<sup>[26]</sup> argued, by contrast, that creativity only involves ordinary cognitive processes yielding extraordinary results.

### **Conceptual blending**

In the '90s, various approaches in cognitive science that dealt with metaphor, analogy and structure mapping have been converging, and a new integrative approach to the study of creativity in science, art and humor has emerged under the label conceptual blending.

*"Creativity is the ability to illustrate what is outside the box from within the box."*

—**The Ride**

### **Creativity and everyday imaginative thought**

In everyday thought, people often spontaneously imagine alternatives to reality when they think "if only...".<sup>[27]</sup> Their counterfactual thinking is viewed as an example of everyday creative processes.<sup>[28]</sup> It has been proposed that the creation of counterfactual alternatives to reality depends on similar cognitive processes to rational thought.<sup>[29]</sup>

## **Psychological examples from science and mathematics**

### **Jacques Hadamard**

Jacques Hadamard, in his book *Psychology of Invention in the Mathematical Field*, uses introspection to describe mathematical thought processes. In contrast to authors who identify language and cognition, he describes his own mathematical thinking as largely wordless, often accompanied by mental images that represent the entire solution to a problem. He surveyed 100 of the leading physicists of his day (ca. 1900), asking them how they did their work. Many of the responses mirrored his own.

Hadamard described the experiences of the mathematicians/theoretical physicists Carl Friedrich Gauss, Hermann von Helmholtz, Henri Poincaré and others as viewing entire solutions with "sudden spontaneity."<sup>[30]</sup>

The same has been reported in literature by many others, such as Denis Brian,<sup>[31]</sup> G. H. Hardy,<sup>[32]</sup> Walter Heitler,<sup>[33]</sup> B. L. van der Waerden,<sup>[34]</sup> and Harold Ruegg.<sup>[35]</sup>

To elaborate on one example, Einstein, after years of fruitless calculations, suddenly had the solution to the general theory of relativity revealed in a dream "like a giant die making an indelible impress, a huge map of the universe outlined itself in one clear vision."<sup>[31]</sup>

Hadamard described the process as having steps (i) preparation, (ii) incubation, (iv) illumination, and (v) verification of the five-step Graham Wallas creative-process model, leaving out (iii) intimation, with the first three cited by Hadamard as also having been put forth by Helmholtz.<sup>[36]</sup>

### **Marie-Louise von Franz**

Marie-Louise von Franz, a colleague of the eminent psychiatrist Carl Jung, noted that in these unconscious scientific discoveries the "always recurring and important factor ... is the simultaneity with which the complete solution is intuitively perceived and which can be checked later by discursive reasoning." She attributes the solution presented "as an archetypal pattern or image."<sup>[37]</sup> As cited by von Franz,<sup>[38]</sup> according to Jung, "Archetypes ... manifest themselves only through their ability to *organize* images and ideas, and this is always an unconscious process which cannot be detected until afterwards."<sup>[39]</sup>

## **Creativity and affect**

Some theories suggest that creativity may be particularly susceptible to affective influence.

### **Creativity and positive affect relations**

According to Alice Isen, positive affect has three primary effects on cognitive activity:

1. Positive affect makes additional cognitive material available for processing, increasing the number of cognitive elements available for association;
2. Positive affect leads to defocused attention and a more complex cognitive context, increasing the breadth of those elements that are treated as relevant to the problem;
3. Positive affect increases cognitive flexibility, increasing the probability that diverse cognitive elements will in fact become associated. Together, these processes lead positive affect to have a positive influence on creativity.

Barbara Fredrickson in her broaden-and-build model suggests that positive emotions such as joy and love broaden a person's available repertoire of cognitions and actions, thus enhancing creativity.

According to these researchers, positive emotions increase the number of cognitive elements available for association (attention scope) and the number of elements that are relevant to the problem (cognitive scope).

Various meta-analyses, such as Matthijs et al. (2008) of 66 studies about creativity and affect support the link between creativity and positive affect<sup>[40]</sup> [41]

### **Creativity and negative affect relations**

On the other hand, some theorists have suggested that negative affect leads to greater creativity. A cornerstone of this perspective is empirical evidence of a relationship between affective illness and creativity. In a study of 1,005 prominent 20th century individuals from over 45 different professions, the University of Kentucky's Arnold Ludwig found a slight but significant correlation between depression and level of creative achievement. In addition, several systematic studies of highly creative individuals and their relatives have uncovered a higher incidence of affective disorders (primarily bipolar disorder and depression) than that found in the general population.

## Creativity and affect at work

Three patterns may exist between affect and creativity at work: positive (or negative) mood, or change in mood, predictably precedes creativity; creativity predictably precedes mood; and whether affect and creativity occur simultaneously.

It was found that not only might affect precede creativity, but creative outcomes might provoke affect as well. At its simplest level, the experience of creativity is itself a work event, and like other events in the organizational context, it could evoke emotion. Qualitative research and anecdotal accounts of creative achievement in the arts and sciences suggest that creative insight is often followed by feelings of elation. For example, Albert Einstein called his 1907 general theory of relativity "the happiest thought of my life." Empirical evidence on this matter is still very tentative.

In contrast to the possible incubation effects of affective state on subsequent creativity, the affective consequences of creativity are likely to be more direct and immediate. In general, affective events provoke immediate and relatively-fleeting emotional reactions. Thus, if creative performance at work is an affective event for the individual doing the creative work, such an effect would likely be evident only in same-day data.

Another longitudinal research found several insights regarding the relations between creativity and emotion at work. First, a positive relationship between positive affect and creativity, and no evidence of a negative relationship. The more positive a person's affect on a given day, the more creative thinking they evidenced that day and the next day—even controlling for that next day's mood. There was even some evidence of an effect two days later.

In addition, the researchers found no evidence that people were more creative when they experienced both positive and negative affect on the same day. The weight of evidence supports a purely linear form of the affect-creativity relationship, at least over the range of affect and creativity covered in our study: the more positive a person's affect, the higher their creativity in a work setting.

Finally, they found four patterns of affect and creativity affect can operate as an antecedent to creativity; as a direct consequence of creativity; as an indirect consequence of creativity; and affect can occur simultaneously with creative activity. Thus, it appears that people's feelings and creative cognitions are interwoven in several distinct ways within the complex fabric of their daily work lives.

## Creativity and intelligence

There has been debate in the psychological literature about whether intelligence and creativity are part of the same process (the conjoint hypothesis) or represent distinct mental processes (the disjoint hypothesis). Evidence from attempts to look at correlations between intelligence and creativity from the 1950s onwards, by authors such as Barron, Guilford or Wallach and Kogan, regularly suggested that correlations between these concepts were low enough to justify treating them as distinct concepts.<sup>[42]</sup>

Some researchers believe that creativity is the outcome of the same cognitive processes as intelligence, and is only judged as creativity in terms of its consequences, i.e. when the outcome of cognitive processes happens to produce something novel, a view which Perkins has termed the "nothing special" hypothesis.<sup>[43]</sup>

A very popular model is what has come to be known as "the threshold hypothesis," proposed by Ellis Paul Torrance, which holds that a high degree of intelligence appears to be a necessary but not sufficient condition for high creativity.<sup>[24]</sup> This implies that, in a general sample, there will be a positive correlation between creativity and intelligence, but this correlation will not be found if only a sample of the most highly intelligent people are assessed. Research into the threshold hypothesis, however, has produced mixed results ranging from enthusiastic support to refutation and rejection.<sup>[44]</sup>

An alternative perspective, Renzulli's three-rings hypothesis, sees giftedness as based on both intelligence and creativity. More on both the threshold hypothesis and Renzulli's work can be found in O'Hara and Sternberg.<sup>[43]</sup>

## Neurobiology of creativity

The neurobiology of creativity has been addressed<sup>[45]</sup> in the article "Creative Innovation: Possible Brain Mechanisms." The authors write that "creative innovation might require coactivation and communication between regions of the brain that ordinarily are not strongly connected." Highly creative people who excel at creative innovation tend to differ from others in three ways:

- they have a high level of specialized knowledge,
- they are capable of divergent thinking mediated by the frontal lobe.
- and they are able to modulate neurotransmitters such as norepinephrine in their frontal lobe.

Thus, the frontal lobe appears to be the part of the cortex that is most important for creativity.

This article also explored the links between creativity and sleep, mood and addiction disorders, and depression.

In 2005, Alice Flaherty presented a three-factor model of the creative drive. Drawing from evidence in brain imaging, drug studies and lesion analysis, she described the creative drive as resulting from an interaction of the frontal lobes, the temporal lobes, and dopamine from the limbic system. The frontal lobes can be seen as responsible for idea generation, and the temporal lobes for idea editing and evaluation. Abnormalities in the frontal lobe (such as depression or anxiety) generally decrease creativity, while abnormalities in the temporal lobe often increase creativity. High activity in the temporal lobe typically inhibits activity in the frontal lobe, and vice versa. High dopamine levels increase general arousal and goal directed behaviors and reduce latent inhibition, and all three effects increase the drive to generate ideas.<sup>[46]</sup>

## Working memory and the cerebellum

Vandervert<sup>[47]</sup> described how the brain's frontal lobes and the cognitive functions of the cerebellum collaborate to produce creativity and innovation. Vandervert's explanation rests on considerable evidence that all processes of working memory (responsible for processing all thought<sup>[48]</sup>) are adaptively modeled by the cerebellum.<sup>[49]</sup> The cerebellum (consisting of 100 billion neurons, which is more than the entirety of the rest of the brain<sup>[50]</sup>) is also widely known to adaptively model all bodily movement. The cerebellum's adaptive models of working memory processing are then fed back to especially frontal lobe working memory control processes<sup>[51]</sup> where creative and innovative thoughts arise.<sup>[52]</sup> (Apparently, creative insight or the "aha" experience is then triggered in the temporal lobe.<sup>[53]</sup>)

According to Vandervert, the details of creative adaptation begin in "forward" cerebellar models which are anticipatory/exploratory controls for movement and thought. These cerebellar processing and control architectures have been termed Hierarchical Modular Selection and Identification for Control (HMOSAIC).<sup>[54]</sup> New, hierarchically arranged levels of the cerebellar control architecture (HMOSAIC) develop as mental mulling in working memory is extended over time. These new levels of the control architecture are fed forward to the frontal lobes. Since the cerebellum adaptively models all movement and all levels of thought and emotion,<sup>[55]</sup> Vandervert's approach helps explain creativity and innovation in sports, art, music, the design of video games, technology, mathematics, the child prodigy, and thought in general.

## REM sleep

Creativity involves the forming of associative elements into new combinations that are useful or meet some requirement. Sleep aids this process.<sup>[56]</sup> REM rather than NREM sleep appears to be responsible.<sup>[57]</sup> <sup>[58]</sup> This has been suggested to be due to changes in cholinergic and noradrenergic neuromodulation that occurs during REM sleep.<sup>[57]</sup> During this period of sleep, high levels of acetylcholine in the hippocampus suppress feedback from the hippocampus to the neocortex, and lower levels of acetylcholine and norepinephrine in the neocortex encourage the spread of associational activity within neocortical areas without control from the hippocampus.<sup>[59]</sup> This is in contrast to waking consciousness, where higher levels of norepinephrine and acetylcholine inhibit recurrent connections in

the neocortex. It is proposed that REM sleep would add creativity by allowing "neocortical structures to reorganize associative hierarchies, in which information from the hippocampus would be reinterpreted in relation to previous semantic representations or nodes."<sup>[57]</sup>

## Creativity and mental health

A study by psychologist J. Philippe Rushton found creativity to correlate with intelligence and psychoticism.<sup>[60]</sup> Another study found creativity to be greater in schizotypal than in either normal or schizophrenic individuals. While divergent thinking was associated with bilateral activation of the prefrontal cortex, schizotypal individuals were found to have much greater activation of their *right* prefrontal cortex.<sup>[61]</sup> This study hypothesizes that such individuals are better at accessing both hemispheres, allowing them to make novel associations at a faster rate. In agreement with this hypothesis, ambidexterity is also associated with schizotypal and schizophrenic individuals. Three recent studies by Mark Batey and Adrian Furnham have demonstrated the relationships between schizotypal<sup>[62]</sup> <sup>[63]</sup> and hypomanic personality <sup>[64]</sup> and several different measures of creativity.

Particularly strong links have been identified between creativity and mood disorders, particularly manic-depressive disorder (a.k.a. bipolar disorder) and depressive disorder (a.k.a. unipolar disorder). In *Touched with Fire: Manic-Depressive Illness and the Artistic Temperament*, Kay Redfield Jamison summarizes studies of mood-disorder rates in **writers, poets and artists**. She also explores research that identifies mood disorders in such famous writers and artists as Ernest Hemingway (who shot himself after electroconvulsive treatment), Virginia Woolf (who drowned herself when she felt a depressive episode coming on), composer Robert Schumann (who died in a mental institution), and even the famed visual artist Michelangelo.

## Measuring creativity

### Creativity quotient

Several attempts have been made to develop a *creativity quotient* of an individual similar to the intelligence quotient (IQ), however these have been unsuccessful.<sup>[65]</sup> Most measures of creativity are dependent on the personal judgement of the tester, so a standardized measure is difficult, if not impossible, to develop.

### Psychometric approach

J. P. Guilford's group,<sup>[24]</sup> which pioneered the modern psychometric study of creativity, constructed several tests to measure creativity in 1967:

- Plot Titles, where participants are given the plot of a story and asked to write original titles.
- Quick Responses is a word-association test scored for uncommonness.
- Figure Concepts, where participants were given simple drawings of objects and individuals and asked to find qualities or features that are common by two or more drawings; these were scored for uncommonness.
- Unusual Uses is finding unusual uses for common everyday objects such as bricks.
- Remote Associations, where participants are asked to find a word between two given words (e.g. Hand \_\_\_\_\_ Call)
- Remote Consequences, where participants are asked to generate a list of consequences of unexpected events (e.g. loss of gravity)

Building on Guilford's work, Torrance<sup>[66]</sup> developed the Torrance Tests of Creative Thinking in 1966. They involved simple tests of divergent thinking and other problem-solving skills, which were scored on:

- **Fluency** – The total number of interpretable, meaningful and relevant ideas generated in response to the stimulus.
- **Originality** – The statistical rarity of the responses among the test subjects.
- **Elaboration** – The amount of detail in the responses.

The Creativity Achievement Questionnaire, a self-report test that measures creative achievement across 10 domains, was described in 2005 and shown to be reliable and valid when compared to other measures of creativity and to independent evaluation of creative output.<sup>[67]</sup> The psychometric approach has been criticized by Robert Sternberg for falling "short of distinguishing imagination from fantasy, relevant from irrelevant material, and contextually valid from rambling associations".

### Social-personality approach

Some researchers have taken a social-personality approach to the measurement of creativity. In these studies, personality traits such as independence of judgement, self-confidence, attraction to complexity, aesthetic orientation and risk-taking are used as measures of the creativity of individuals.<sup>[18]</sup> Other researchers<sup>[68]</sup> have related creativity to the trait, *openness to experience*.

As the research into the relationship between personality traits and creativity continues to grow, a more complete picture has developed. Within the framework of the Big Five model of personality some consistent traits have emerged.<sup>[42]</sup> Openness to experience has been shown to be consistently related to a whole host of different assessments of creativity.<sup>[69]</sup> Among the other Big Five traits, research has demonstrated subtle differences between different domains of creativity. A meta-analysis by Gregory Feist showed that artists tend to have higher levels of neuroticism and introversion, while scientists are more conscientiousness.<sup>[70]</sup>

### Other approaches to measurement

Genrich Altshuller in the 1950s introduced approaching creativity as an *exact science* with TRIZ and a Level-of-Invention measure.

The creativity of thousands of Japanese, expressed in terms of their problem-solving and problem-recognizing capabilities, has been measured in Japanese firms.<sup>[71]</sup>

Howard Gruber insisted on a case-study approach that expresses the existential and unique quality of the creator. Creativity to Gruber was the product of purposeful work and this work could be described only as a confluence of forces in the specifics of the case.

### Creativity in various contexts

Creativity has been studied from a variety of perspectives and is important in numerous contexts. Most of these approaches are undisciplinatory, and it is therefore difficult to form a coherent overall view.<sup>[18]</sup> The following sections examine some of the areas in which creativity is seen as being important.

#### Creativity Profiles

Creativity comes in different forms. A number of different theorists have suggested models of the creative person. One model suggests that there



An electric wire reel reused like a center table in a Rio de Janeiro decoration fair. The creativity of this designer in reusing this waste was used with good effects to the environment.

are kinds to produce growth, innovation, speed, etc. These are referred to as the four "Creativity Profiles" that can help achieve such goals.<sup>[72]</sup>

- (i) *Incubate* (Long-term Development)
- (ii) *Imagine* (Breakthrough Ideas)
- (iii) *Improve* (Incremental Adjustments)
- (iv) *Invest* (Short-term Goals)

Research by Dr Mark Batey of the Psychometrics at Work Research Group at Manchester Business School has suggested that the creative profile can be explained by four primary creativity traits with narrow facets within each

- (i) "Idea Generation" (Fluency, Originality, Incubation and Illumination)
- (ii) "Personality" (Curiosity and Tolerance for Ambiguity)
- (iii) "Motivation" (Intrinsic, Extrinsic and Achievement)
- (iv) "Confidence" (Producing, Sharing and Implementing)

This model was developed in a sample of 1000 working adults using the statistical techniques of Exploratory Factor Analysis followed by Confirmatory Factor Analysis by Structural Equation Modelling.<sup>[73]</sup>

An important aspect of the creativity profiling approach is to account for the tension between predicting the creative profile of an individual, as characterised by the psychometric approach, and the evidence that team creativity is founded on diversity and difference.<sup>[74]</sup>

### Creativity in diverse cultures

Francois Jullien in "Process and Creation, 1989" is inviting us to look at that concept from a Chinese cultural point of view. Fangqi Xu<sup>[75]</sup> has reported creativity courses in a range of countries. Todd Lubart has studied extensively the cultural aspects of creativity and innovation.

### Creativity in art and literature



Henry Moore's *Reclining Figure*

Most people associate creativity with the fields of art and literature. In these fields, *originality* is considered to be a sufficient condition for creativity, unlike other fields where both *originality* and *appropriateness* are necessary.<sup>[76]</sup>

Within the different modes of artistic expression, one can postulate a continuum extending from "interpretation" to "innovation". Established artistic movements and genres pull practitioners to the "interpretation" end of the scale,

whereas original thinkers strive towards the "innovation" pole. Note that we conventionally expect some "creative" people (dancers, actors, orchestral members, etc.) to perform (interpret) while allowing others (writers, painters, composers, etc.) more freedom to express the new and the different.

Contrast alternative theories, for example:

- artistic inspiration, which provides the transmission of visions from divine sources such as the Muses; a taste of the Divine. Compare with invention.

- artistic evolution, which stresses obeying established ("classical") rules and imitating or appropriating to produce subtly different but unshockingly understandable work. Compare with crafts.
- artistic conversation, as in Surrealism, which stresses the depth of communication when the creative product is the language.

In the art practice and theory of Davor Dzalto, human creativity is taken as a basic feature of both the personal existence of human being and art production. For this thinker, creativity is a basic cultural and anthropological category, since it enables human manifestation in the world as a "real presence" in contrast to the progressive "virtualization" of the world.

## Creative industries and services

Today, creativity forms the core activity of a growing section of the global economy—the so-called "creative industries"—capitalistically generating (generally non-tangible) wealth through the creation and exploitation of intellectual property or through the provision of creative services. The Creative Industries Mapping Document 2001<sup>[77]</sup> provides an overview of the creative industries in the UK. The creative professional workforce is becoming a more integral part of industrialized nations' economies.

Creative professions include writing, art, design, theater, television, radio, motion pictures, related crafts, as well as marketing, strategy, some aspects of scientific research and development, product development, some types of teaching and curriculum design, and more. Since many creative professionals (actors and writers, for example) are also employed in secondary professions, estimates of creative professionals are often inaccurate. By some estimates, approximately 10 million US workers are creative professionals; depending upon the depth and breadth of the definition, this estimate may be double.

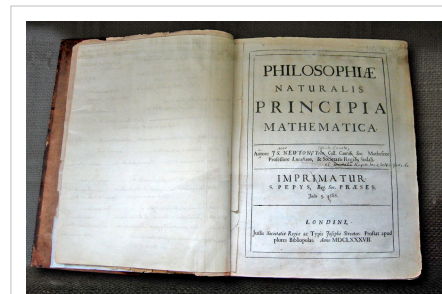
## Creativity in other professions

Creativity is also seen as being increasingly important in a variety of other professions. Architecture and industrial design are the fields most often associated with creativity, and more generally the fields of design and design research. These fields explicitly value creativity, and journals such as *Design Studies* have published many studies on creativity and creative problem solving.<sup>[78]</sup>

Fields such as science and engineering have, by contrast, experienced a less explicit (but arguably no less important) relation to creativity. Simonton<sup>[23]</sup> shows how some of the major scientific advances of the 20th century can be attributed to the creativity of individuals. This ability will also be seen as increasingly important for engineers in years to come.<sup>[79]</sup>

Accounting has also been associated with creativity with the popular euphemism *creative accounting*. Although this term often implies unethical practices, Amabile<sup>[76]</sup> has suggested that even this profession can benefit from the (ethical) application of creative thinking.

In a recent global survey of approximately 1600 CEO's, the leadership trait that was considered to be most crucial for success was creativity.<sup>[80]</sup> This suggests that the world of business is beginning to accept that creativity is of value in a diversity of industries, rather than being simply the preserve of the creative industries.



Isaac Newton's law of gravity is popularly attributed to a *creative leap* he experienced when observing a falling apple.



## Creativity in organizations

Amabile<sup>[76]</sup> argued that to enhance creativity in business, three components were needed:

- Expertise (technical, procedural and intellectual knowledge),
- Creative thinking skills (how flexibly and imaginatively people approach problems),
- and Motivation (especially intrinsic motivation).

There are two types of motivation:

- extrinsic motivation – external factors, for example threats of being fired or money as a reward,
- intrinsic motivation – comes from inside an individual, satisfaction, enjoyment of work etc.

Six managerial practices to encourage motivation are:

- Challenge – matching people with the right assignments;
- Freedom – giving people autonomy choosing means to achieve goals;
- Resources – such as time, money, space etc. There must be balance fit among resources and people;
- Work group features – diverse, supportive teams, where members share the excitement, willingness to help and recognize each other's talents;
- Supervisory encouragement – recognitions, cheering, praising;
- Organizational support – value emphasis, information sharing, collaboration.

Nonaka, who examined several successful Japanese companies, similarly saw creativity and knowledge creation as being important to the success of organizations.<sup>[81]</sup> In particular, he emphasized the role that tacit knowledge has to play in the creative process.

In business, originality is not enough. The idea must also be appropriate—useful and actionable.<sup>[82]</sup>

## Economic views of creativity

Economic approaches to creativity have focussed on three aspects - the impact of creativity on economic growth, methods of modelling markets for creativity, and the maximisation of economic creativity (innovation).

In the early 20th century, Joseph Schumpeter introduced the economic theory of *creative destruction*, to describe the way in which old ways of doing things are endogenously destroyed and replaced by the new. Some economists (such as Paul Romer) view creativity as an important element in the recombination of elements to produce new technologies and products and, consequently, economic growth. Creativity leads to capital, and creative products are protected by intellectual property laws.

Mark A. Runco and Daniel Rubenson have tried to describe a "psychoeconomic" model of creativity.<sup>[83]</sup> In such a model, creativity is the product of endowments and active investments in creativity; the costs and benefits of bringing creative activity to market determine the supply of creativity. Such an approach has been criticised for its view of creativity consumption as always having positive utility, and for the way it analyses the value of future innovations.<sup>[84]</sup>

The *creative class* is seen by some to be an important driver of modern economies. In his 2002 book, *The Rise of the Creative Class*, economist Richard Florida popularized the notion that regions with "3 T's of economic development: Technology, Talent and Tolerance" also have high concentrations of creative professionals and tend to have a higher level of economic development.

## Fostering creativity

Daniel Pink, in his 2005 book *A Whole New Mind*, repeating arguments posed throughout the 20th century, argues that we are entering a new age where creativity is becoming increasingly important. In this *conceptual age*, we will need to foster and encourage *right-directed thinking* (representing creativity and emotion) over *left-directed thinking* (representing logical, analytical thought). However, this simplification of 'right' versus 'left' brain thinking is not supported by the research data.<sup>[85]</sup>

Nickerson<sup>[86]</sup> provides a summary of the various creativity techniques that have been proposed. These include approaches that have been developed by both academia and industry:

1. Establishing purpose and intention
2. Building basic skills
3. Encouraging acquisitions of domain-specific knowledge
4. Stimulating and rewarding curiosity and exploration
5. Building motivation, especially internal motivation
6. Encouraging confidence and a willingness to take risks
7. Focusing on mastery and self-competition
8. Promoting supportable beliefs about creativity
9. Providing opportunities for choice and discovery
10. Developing self-management (metacognitive skills)
11. Teaching techniques and strategies for facilitating creative performance
12. Providing balance

Some see the conventional system of schooling as "stifling" of creativity and attempt (particularly in the pre-school/kindergarten and early school years) to provide a creativity-friendly, rich, imagination-fostering environment for young children.<sup>[86] [87] [88]</sup> Researchers have seen this as important because technology is advancing our society at an unprecedented rate and creative problem solving will be needed to cope with these challenges as they arise.<sup>[88]</sup> In addition to helping with problem solving, creativity can also help students identify problems where others have failed to do so.<sup>[86] [87] [89]</sup> See the Waldorf School as an example of an education program that promotes creative thought.

Promoting intrinsic motivation and problem solving are two areas where educators can foster creativity in students. Students are more creative when they see a task as intrinsically motivating, valued for its own sake.<sup>[87] [88] [90] [91]</sup> To promote creative thinking educators need to identify what motivates their students and structure teaching around it. Providing students with a choice of activities to complete allows them to become more intrinsically motivated and therefore creative in completing the tasks.<sup>[86] [92]</sup>

Teaching students to solve problems that do not have well defined answers is another way to foster their creativity. This is accomplished by allowing students to explore problems and redefine them, possibly drawing on knowledge that at first may seem unrelated to the problem in order to solve it.<sup>[86] [87] [88] [90]</sup>

Several different researchers have proposed methods of increasing the creativity of an individual. Such ideas range from the psychological-cognitive, such as Osborn-Parnes Creative Problem Solving Process, Synectics, Science-based creative thinking, Purdue Creative Thinking Program, and Edward de Bono's lateral thinking; to the highly-structured, such as TRIZ (the Theory of Inventive Problem-Solving) and its variant Algorithm of Inventive Problem Solving (developed by the Russian scientist Genrich Altshuller), and Computer-Aided Morphological analysis.

## Understanding and enhancing the creative process with new technologies

A simple but accurate review <sup>[93]</sup> on this new Human-Computer Interactions (HCI) angle for promoting creativity has been written by Todd Lubart, an invitation full of creative ideas to develop further this new field.

Groupware and other Computer Supported Collaborative Work (CSCW) platforms are now the stage of Network Creativity on the web or on other private networks. These tools have made more obvious the existence of a more connective, cooperative and collective nature of creativity rather than the prevailing individual one. Creativity Research on Global Virtual Teams <sup>[94]</sup> is showing that the creative process is affected by the national identities, cognitive and conative profiles, anonymous interactions at times and many other factors affecting the teams members, depending on the early or later stages of the cooperative creative process. They are also showing how NGO's cross-cultural virtual team's innovation in Africa would also benefit from the pooling of best global practices online. Such tools enhancing cooperative creativity may have a great impact on society and as such should be tested while they are built following the Motto: "Build the Camera while shooting the film". Some European FP7 scientific programs like Paradiso <sup>[95]</sup> are answering a need for advanced experimentally-driven research including large scale experimentation test-beds to discover the technical, societal and economic implications of such groupware and collaborative tools to the Internet.

On the other hand, creativity research may one day be pooled with a computable metalanguage like IEML <sup>[96]</sup> from the University of Ottawa Collective Intelligence Chair, Pierre Levy. It might be a good tool to provide an interdisciplinary definition and a rather unified theory of creativity. The creative processes being highly fuzzy, the programming of cooperative tools for creativity and innovation should be adaptive and flexible. Empirical Modelling <sup>[97]</sup> seems to be a good choice for Humanities Computing.

If all the activity of the universe could be traced with appropriate captors, it is likely that one could see the creative nature of the universe to which humans are active contributors. After the web of documents, the Web of Things might shed some light on such a universal creative phenomenon which should not be restricted to humans. In order to trace and enhance cooperative and collective creativity, Metis Reflexive Global Virtual Team has worked for the last few years on the development of a Trace Composer <sup>[98]</sup> at the intersection of personal experience and social knowledge.

Metis Reflexive Team has also identified a paradigm for the study of creativity to bridge European theory of "useless" and non-instrumentalized creativity, North American more pragmatic creativity and Chinese culture stressing more creativity as a holistic process of continuity rather than radical change and originality. This paradigm is mostly based on the work of the German philosopher Hans Joas, one that emphasizes the creative character of human action. This model allows also for a more comprehensive theory of action. Joas elaborates some implications of his model for theories of social movements and social change. The connection between concepts like creation, innovation, production and expression is facilitated by the creativity of action <sup>[99]</sup> as a metaphore but also as a scientific concept.

The Creativity and Cognition conference series, sponsored by the ACM and running since 1993, has been an important venue for publishing research on the intersection between technology and creativity. The conference now runs biennially, next taking place in 2011.

## Social attitudes to creativity

Although the benefits of creativity to society as a whole have been noted,<sup>[100]</sup> social attitudes about this topic remain divided. The wealth of literature regarding the development of creativity<sup>[101]</sup> and the profusion of creativity techniques indicate wide acceptance, at least among academics, that creativity is desirable.

There is, however, a dark side to creativity, in that it represents a "*quest for a radical autonomy apart from the constraints of social responsibility*".<sup>[102]</sup> In other words, by encouraging creativity we are encouraging a departure from society's existing norms and values. Expectation of conformity runs contrary to the spirit of creativity. Sir Ken Robinson argues that the current education system is "educating people out of their creativity".<sup>[103]</sup> <sup>[104]</sup>

Nevertheless, employers are increasingly valuing creative skills. A report by the Business Council of Australia, for example, has called for a higher level of creativity in graduates.<sup>[105]</sup> The ability to "think outside the box" is highly sought after. However, the above-mentioned paradox may well imply that firms pay lip service to thinking outside the box while maintaining traditional, hierarchical organization structures in which individual creativity is not rewarded.

## Notes

- [1] Runco, Mark A.; Albert, Robert S. (2010). "Creativity Research". In James C. Kaufman and Robert J. Sternberg. *The Cambridge Handbook of Creativity*. Cambridge University Press. ISBN 978-0-521-73025-9.
- [2] "And eke Job saith, that in hell is no order of rule. And albeit that God hath **created** all things in right order, and nothing without order, but all things be ordered and numbered, yet nevertheless they that be damned be not in order, nor hold no order."
- [3] Mumford, M. D. (2003). Where have we been, where are we going? Taking stock in creativity research. *Creativity Research Journal*, 15, 107–120.
- [4] Meusbürger, Peter (2009). "Milieus of Creativity: The Role of Places, Environments and Spatial Contexts". In Meusbürger, P., Funke, J. and Wunder, E.. *Milieus of Creativity: An Interdisciplinary Approach to Spatiality of Creativity*. Springer. ISBN 1402098766, 9781402098765.
- [5] Kozbelt, Aaron; Beghetto, Ronald A. and Runco, Mark A. (2010). "Theories of Creativity". In James C. Kaufman and Robert J. Sternberg. *The Cambridge Handbook of Creativity*. Cambridge University Press. ISBN 978-0-521-73025-9.
- [6] Gabora, Liane (1997). "The Origin and Evolution of Culture and Creativity" (<http://cogprints.org/794/1/oecc.html>). *Journal of Memetics - Evolutionary Models of Information Transmission* 1. .
- [7] Csíkszentmihályi, Mihály (1996). *Creativity: Flow and the Psychology of Discovery and Invention*. Harper Collins. ISBN 0060928204, 978-0060928209.
- [8] Simonton, D. K. (1997). "Creative Productivity: A Predictive and Explanatory Model of Career Trajectories and Landmarks". *Psychological Review* 104 (1): 66–89.
- [9] Robinson, Ken (1998). *All our futures: Creativity, culture, education* (<http://sirkenrobinson.com/skr/pdf/allourfutures.pdf>). National Advisory Committee on Creative and Cultural Education. . Retrieved 2 October 2010.
- [10] Craft, Anna (2001). "Little C' creativity". In Craft, A., Jeffrey, B. and Leibling, M.. *Creativity in education*. Continuum International. ISBN 0826448631, 9780826448637.
- [11] Boden, Margaret (2004). *The Creative Mind: Myths And Mechanisms*. Routledge. ISBN 0297820699..
- [12] Kaufman, James C.; Beghetto, Ronald A. (2009). "Beyond Big and Little: The Four C Model of Creativity". *Review of General Psychology* 13 (1): 1–12. doi:10.1037/a0013688.
- [13] Dacey, John (1999). "Concepts of Creativity: A history". In Mark A. Runco and Steven R. Pritzler. *Encyclopedia of Creativity, Vol. 1*. Elsevier. ISBN 0122270762.
- [14] Albert, R. S.; Runco, M. A. (1999). "A History of Research on Creativity". In Sternberg, R. J.. *Handbook of Creativity*. Cambridge University Press.
- [15] Niu, Weihua; Sternberg, Robert J. (2006). "The Philosophical Roots of Western and Eastern Conceptions of Creativity" ([http://www.westga.edu/~stpp/JTTPP\\_Articles/26-2/THE1210.pdf](http://www.westga.edu/~stpp/JTTPP_Articles/26-2/THE1210.pdf)). *Journal of Theoretical and Philosophical Psychology* 26: 18–38. doi:10.1037/h0091265. . Retrieved 23 October 2010.
- [16] Tatarkiewicz, Władysław (1980). *A History of Six Ideas: an Essay in Aesthetics*. Translated from the Polish by Christopher Kasperek, The Hague: Martinus Nijhoff.
- [17] Wallas, G. (1926). *Art of Thought*.
- [18] Sternberg, R. J.; Lubart, T. I. (1999). "The Concept of Creativity: Prospects and Paradigms". In ed. Sternberg, R. J.. *Handbook of Creativity*. Cambridge University Press. ISBN 0521572851.
- [19] (Hargreaves, H. L. (1927). "The faculty of imagination: An enquiry concerning the existence of a general faculty, or group factor, of imagination." *British Journal of Psychology Monograph Supplement* 3: 1-74.)
- [20] Ward, T. (2003). "Creativity". In ed. Nagel, L.. *Encyclopaedia of Cognition*. New York: Macmillan.

- [21] Smith, Steven M. (1995). "Fixation, Incubation, and Insight in Memory and Creative Thinking". In Steven M. Smith, Thomas B. Ward and Ronald A. Finke. *The Creative Cognition Approach*. MIT Press.
- [22] "Anderson, J. R. (2000). *Cognitive psychology and its implications*. Worth Publishers. ISBN 0716716860.
- [23] Simonton, D. K. (1999). *Origins of genius: Darwinian perspectives on creativity*. Oxford University Press.
- [24] Guilford, J. P. (1967). *The Nature of Human Intelligence*.
- [25] Koestler, A. (1964). *The Act of Creation*. London: Pan Books. ISBN 0330731165.
- [26] Weisberg, R. W. (1993). *Creativity: Beyond the myth of genius*. Freeman. ISBN 0716721198.
- [27] Roeser, N. J. & Olson, J. M. (1995). *What Might Have Been: The Social Psychology of Counterfactual Thinking*. Mahwah, New Jersey: Erlbaum
- [28] Markman, K. Klein, W. & Suhr, E. (eds) (2009). *Handbook of mental simulation and the human imagination*. Hove, Psychology Press
- [29] Byrne, R. M. J. (2005). *The Rational Imagination: How People Create Counterfactual Alternatives to Reality*. Cambridge, MA: MIT Press.
- [30] Hadamard, 1954, pp. 13-16.
- [31] Brian, 1996, p. 159.
- [32] G. H. Hardy cited how the mathematician Srinivasa Ramanujan had "moments of sudden illumination." See Kanigel, 1992, pp. 285-286.
- [33] Interview with Walter Heitler by John Heilbron (March 18, 1963. Archives for the History of Quantum Physics), as cited in and quoted from in Gavroglu, Kostas *Fritz London: A Scientific Biography* p. 45 (Cambridge, 2005).
- [34] von Franz, 1992, p. 297 and 314. Cited work: B. L. van der Waerden, *Einfall und Überlegung: Drei kleine Beiträge zur Psychologie des mathematischen Denkens* (Gasel & Stuttgart, 1954).
- [35] von Franz, 1992, p. 297 and 314. Cited work: Harold Ruegg, *Imagination: An Inquiry into the Sources and Conditions That Stimulate Creativity* (New York: Harper, 1954).
- [36] Hadamard, 1954, p. 56.
- [37] von Franz, 1992, pp. 297-298.
- [38] von Franz, 1992 297-298 and 314.
- [39] Jung, 1981, paragraph 440, p. 231.
- [40] Mark A. Davis (January 2009). "Understanding the relationship between mood and creativity: A meta-analysis" ([http://www.sciencedirect.com/science?\\_ob=ArticleURL&\\_udi=B6WP2-4SJR2DD-2&\\_user=10&\\_coverDate=01/31/2009&\\_rdoc=1&\\_fmt=high&\\_orig=search&\\_origin=search&\\_sort=d&\\_docanchor=&view=c&\\_searchStrId=1591960036&\\_rerunOrigin=scholar.google&\\_acct=C000050221&\\_version=1&\\_urlVersion=0&\\_userid=10&md5=124ef41f3adc2879e442ae692bd64fc1&searchtype=a](http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6WP2-4SJR2DD-2&_user=10&_coverDate=01/31/2009&_rdoc=1&_fmt=high&_orig=search&_origin=search&_sort=d&_docanchor=&view=c&_searchStrId=1591960036&_rerunOrigin=scholar.google&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=124ef41f3adc2879e442ae692bd64fc1&searchtype=a)). *Organizational Behavior and Human Decision Processes* **100** (1): 25–38. doi:10.1016/j.obhdp.2008.04.001. .
- [41] Baas, Matthijs; De Dreu, Carsten K. W.; Nijstad, Bernard A. (November 2008). "A meta-analysis of 25 years of mood-creativity research: Hedonic tone, activation, or regulatory focus?" ([http://home.medewerker.uva.nl/m.baas/bestanden/MBaas\\_mood-creativity.pdf](http://home.medewerker.uva.nl/m.baas/bestanden/MBaas_mood-creativity.pdf)). *Psychological Bulletin* **134** (6): 779–806. doi:10.1037/a0012815. .
- [42] Batey, M. & Furnham, A. (2006). Creativity, intelligence and personality: A critical review of the scattered literature. *Genetic, Social, and General Psychology Monographs*, 132, p. 355-429.
- [43] (O'Hara & Sternberg, 1999).
- [44] (Plucker & Renzulli, 1999)
- [45] (Kenneth M Heilman, MD, Stephen E. Nadeau, MD, and David Q. Beversdorf, MD. "Creative Innovation: Possible Brain Mechanisms" *Neurocase* (2003) (<http://neurology.med.ohio-state.edu/cognitivelab/CreativityMechanisms.pdf>)
- [46] Flaherty AW. (2005). Frontotemporal and dopaminergic control of idea generation and creative drive. *J Comp Neurol.* 493(1):147-53. PMID 16254989
- [47] Vandervert 2003a, 2003b; Vandervert, Schimpf & Liu, 2007
- [48] Miyake & Shah, 1999
- [49] Schmähmann, 1997, 2004
- [50] Andersen, Korbo & Pakkenberg, 1992.
- [51] Miller & Cohen, 2001
- [52] Vandervert, 2003a
- [53] Jung-Beeman, Bowden, Haberman, Frymiare, Arambel-Liu, Greenblatt, Reber & Kounios, 2004
- [54] Imamizu, Kuroda, Miyauchi, Yoshioka & Kawato, 2003
- [55] Schmähmann, 2004,
- [56] Wagner U., Gais S., Haider H., Verleger R., Born J. (2004). Sleep inspires insight. *Nature.* 427(6972):352-5. PMID 14737168
- [57] Cai D. J., Mednick S. A., Harrison E. M., Kanady J. C., Mednick S. C. (2009). REM, not incubation, improves creativity by priming associative networks. *Proc Natl Acad Sci U S A.* 106: 10130–10134. PMID 19506253
- [58] Walker M. P., Liston C., Hobson J. A., Stickgold R. (2002). Cognitive flexibility across the sleep-wake cycle: REM-sleep enhancement of anagram problem solving. *Brain Res Cogn Brain Res.* 14(3):317-24. PMID 12421655
- [59] Hasselmo M.E. (1999). Neuromodulation: acetylcholine and memory consolidation. *Trends Cogn Sci.* 3(9):351-359. PMID 10461198
- [60] (Rushton, 1990)
- [61] [http://exploration.vanderbilt.edu/news/news\\_schizotypes.htm](http://exploration.vanderbilt.edu/news/news_schizotypes.htm) ( Actual paper (<http://dx.doi.org/10.1016/j.schres.2005.06.016>))
- [62] Batey, M. Furnham, A. (2009). The relationship between creativity, schizotypy and intelligence. *Individual Differences Research*, 7, p.272-284.

- [63] Batey, M. & Furnham, A. (2008). The relationship between measures of creativity and schizotypy. *Personality and Individual Differences*, 45, p.816-821.
- [64] Furnham, A., Batey, M., Anand, K. & Manfield, J. (2008). Personality, hypomania, intelligence and creativity. *Personality and Individual Differences*, 44, p.1060-1069.
- [65] (Kraft, 2005)
- [66] (Torrance, 1974)
- [67] (Carson, 2005)
- [68] for example McCrae (1987)
- [69] Batey, M., Furnham, A. F. & Safiullina, X. (2010). Intelligence, General Knowledge and Personality as Predictors of Creativity. *Learning and Individual Differences*, 20, p. 532-535.
- [70] Feist, G. J. (1998). A meta-analysis of the impact of personality on scientific and artistic creativity. *Personality and Social Psychological Review*, 2, 290–309.
- [71] "ICC Creativity Test" (<http://www.f6.dion.ne.jp/~iccinc/#English>). International Counseling Center, Tokyo. 2003. . Retrieved 26 November 2010.
- [72] (DeGraff, Lawrence 2002)
- [73] (Batey & Irwing, 2010) <http://www.e-metrix.com/creativity-profit/me2-spec/>
- [74] Nijstad, B. A. and De Dreu, C. K. (2002), Creativity and Group Innovation. *Applied Psychology*, 51: 400–406. doi: 10.1111/1464-0597.00984
- [75] [[Fangqi Xu (<http://www.cct.umb.edu/fangqi.pdf>), et al. *A Survey of Creativity Courses at Universities in Principal Countries*]
- [76] (Amabile, 1998; Sullivan and Harper, 2009)
- [77] [http://www.culture.gov.uk/global/publications/archive\\_2001/ci\\_mapping\\_doc\\_2001.htm](http://www.culture.gov.uk/global/publications/archive_2001/ci_mapping_doc_2001.htm)
- [78] For a typical example see (Dorst et al., 2001).
- [79] National Academy of Engineering (2005).
- [80] <http://www-03.ibm.com/press/us/en/pressrelease/31670.wss>
- [81] (Nonaka, 1991)
- [82] Amabile, T. M. (1998). "How to kill creativity". *Harvard Business Review*
- [83] Rubenson, Daniel L.; Runco, Mark (1992). "The psychoeconomic approach to creativity". *New Ideas in Psychology* 10 (2): 131–147. doi:10.1016/0732-118X(92)90021-Q.
- [84] Diamond, Arthur M. (1992). "Creativity and Interdisciplinarity: A Response to Rubenson and Runco". *New Ideas in Psychology* 10 (2): 157–160. doi:10.1016/0732-118X(92)90023-S.
- [85] <http://www.psychologytoday.com/blog/lives-the-brain/201004/creativity-the-brain-and-evolution>
- [86] Nickerson, R. S. (1999). "Enhancing creativity". In R. J. Sternberg, *Handbook of Creativity*. Cambridge University Press.
- [87] Csikszentmihályi, Mihály (1999). "Implications of a systems perspective for the study of creativity". In R. J. Sternberg, *Handbook of Creativity*. Cambridge University Press.
- [88] Robinson, K.; Azzam, A. M. (2009). "Why creativity now?". *Educational Leadership* 67 (1): 22–26.
- [89] Paris, C., Edwards, N., Sheffield, E., Mutinsky, M., Olexa, T., Reilly, S., & Baer, J. (2006). How early school experiences impact creativity. In J. C. Kaufman & J. Baer (Eds.), *Creativity and Reason in Cognitive Development* (pp. 333-350). New York, NY: Cambridge University Press.
- [90] Byrge, C.; Hanson, S. (2009). "The creative platform: A new paradigm for teaching creativity". *Problems of Education in the 21st Century* 18: 33–50.
- [91] Csikszentmihalyi, M. (1993). Evolution and flow. In M. Csikszentmihalyi (Ed.), *The evolving self: A psychology for the third millennium* (pp. 175-206). New York: Harper Perennial.
- [92] National Advisory Committee on Creative and Cultural Education (1998). *All our futures: Creativity, culture, and education*. UK: NACCCE
- [93] [http://www.sciencedirect.com/science?\\_ob=ArticleURL&\\_udi=B6WGR-4G65VJ1-1&\\_user=10&\\_coverDate=10%2F31%2F2005&\\_alid=527112635&\\_rdoc=1&\\_fmt=summary&\\_orig=search&\\_cdi=6829&\\_sort=d&\\_docanchor=&view=c&\\_acct=C000050221&\\_version=1&\\_urlVersion=0&\\_userid=10&md5=3ad4369ed718542426a8f4ace61c7d8f](http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6WGR-4G65VJ1-1&_user=10&_coverDate=10%2F31%2F2005&_alid=527112635&_rdoc=1&_fmt=summary&_orig=search&_cdi=6829&_sort=d&_docanchor=&view=c&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=3ad4369ed718542426a8f4ace61c7d8f)
- [94] <http://www.informatik.uni-trier.de/~ley/db/indices/a-tree/l/Letaief:Rafik.html>
- [95] <http://www.paradiso-fp7.eu/>
- [96] <http://www.ieml.org>
- [97] <http://www2.warwick.ac.uk/fac/sci/dcs/research/em/publications/papers/091>
- [98] <http://www.iamot.org/conference/index.php/ocs/10/paper/view/1351/604>
- [99] <http://www.press.uchicago.edu/presssite/metadata/epl?mode=synopsis&bookkey=45339>
- [100] (Runco 2004)
- [101] see (Feldman, 1999) for example
- [102] (McLaren, 1999)
- [103] <http://www.youtube.com/watch?v=cod5az5EcX0>
- [104] <http://www.youtube.com/watch?v=mddD1yGREKQ&feature=related>
- [105] (BCA, 2006)

## References

- Amabile, Teresa M.; Barsade, Sigal G; Mueller, Jennifer S; Staw, Barry M., "Affect and creativity at work," *Administrative Science Quarterly*, 2005, vol. 50, pp. 367–403.
- Amabile, T. M. (1998). "How to kill creativity". *Harvard Business Review* **76** (5).
- Amabile, T. M. (1996). *Creativity in context*. Westview Press.
- Ayan, Jordan (1997). *Aha! - 10 Ways To Free Your Creative Spirit and Find Your Great Ideas*. Random House. ISBN 0517884003.
- Balzac, Fred (2006). "Exploring the Brain's Role in Creativity". *NeuroPsychiatry Reviews* **7** (5): 1, 19–20.
- BCA (2006). *New Concepts in Innovation: The Keys to a Growing Australia*. Business Council of Australia (<http://www.bca.com.au>).
- Brian, Denis, *Einstein: A Life* (John Wiley and Sons, 1996) ISBN 0-471-11459-6
- Byrne, R. M. J. (2005). *The Rational Imagination: How People Create Counterfactual Alternatives to Reality*. MIT Press.
- Carson, S. H.; Peterson, J. B., Higgins, D. M. (2005). "Reliability, Validity, and Factor Structure of the Creative Achievement Questionnaire". *Creativity Research Journal* **17** (1): 37–50. doi:10.1207/s15326934crj1701\_4.
- Craft, A. (2005). *Creativity in Schools: tensions and dilemmas*. Routledge. ISBN 0415324149.
- Dorst, K.; Cross, N. (2001). "Creativity in the design process: co-evolution of problem–solution". *Design Studies* **22** (5): 425–437. doi:10.1016/S0142-694X(01)00009-6.
- Feldman, D. H. (1999). "The Development of Creativity". In ed. Sternberg, R.J.. *Handbook of Creativity*. Cambridge University Press.
- Finke, R.; Ward, T. B. & Smith, S. M. (1992). *Creative cognition: Theory, research, and applications*. MIT Press. ISBN 0262061503.
- Flaherty, A. W. (2005). "Frontotemporal and dopaminergic control of idea generation and creative drive". *Journal of Comparative Neurology* **493** (1): 147–153. doi:10.1002/cne.20768. PMC 2571074. PMID 16254989.
- Florida, R. (2002). *The Rise of the Creative Class: And How It's Transforming Work, Leisure, Community and Everyday Life*. Basic Books. ISBN 0465024769.
- Fredrickson, B. L., "The role of positive emotions in positive psychology: The broaden-and-build theory of positive emotions," *American Psychologist*, vol. 56 (2001), pp. 218–26.
- Hadamard, Jacques, *The Psychology of Invention in the Mathematical Field* (Dover, 1954) ISBN 0-486-20107-4
- Helmholtz, H. v. L. (1896). *Vorträge und Reden (5th edition)*. Friederich Vieweg und Sohn.
- Isen A. M., Daubman K. A. & Nowicki G. P., "Positive affect facilitates creative problem solving," *Journal of Personality and Social Psychology*, vol. 52 (1987), pp. 1122–31.
- Jeffery, G. (2005). *The Creative College: building a successful learning culture in the arts*. Trentham Books.
- Johnson, D. M. (1972). *Systematic introduction to the psychology of thinking*. Harper & Row.
- Jullien, F.; Paula M. Varsano (translator) (2004). *In Praise of Blandness: Proceeding from Chinese Thought and Aesthetics*. Zone Books, U.S.. ISBN 1-890951-41-2; ISBN 978-1-890951-41-2
- Jung, C. G., *The Collected Works of C. G. Jung. Volume 8. The Structure and Dynamics of the Psyche*. (Princeton, 1981) ISBN 0-691-09774-7
- Kanigel, Robert, *The Man Who Knew Infinity: A Life of the Genius Ramanujan* (Washington Square Press, 1992) ISBN 0-671-75061-5
- Kraft, U. (2005). "Unleashing Creativity". *Scientific American Mind* **April**: 16–23.
- Kolp, P., Lammé, A., Regnard, Fr., Rens, J. M. (ed.) (2009). "Musique et créativité". *Orphée Apprenti* (Conseil de la Musique) **NS** (1): 9–119. D/2009/11848/5
- McLaren, R. B. (1999). "Dark Side of Creativity". In ed. Runco, M. A. & Pritzker, S. R.. *Encyclopedia of Creativity*. Academic Press.
- McCrae, R. R. (1987). "Creativity, Divergent Thinking, and Openness to Experience". *Journal of Personality and Social Psychology* **52** (6): 1258–1265. doi:10.1037/0022-3514.52.6.1258.

- Michalko, M. (1998). *Cracking Creativity: The Secrets of Creative Genius*. Berkeley, Calif.: Ten Speed Press. ISBN 089815913X.
- Nachmanovitch, Stephen (1990). *Free Play: Improvisation in Life and Art*. Penguin-Putnam. ISBN 0874775787.
- National Academy of Engineering (2005). *Educating the engineer of 2020: adapting engineering education to the new century*. National Academies Press. ISBN 0309096499.
- Nonaka, I. (1991). "The Knowledge-Creating Company". *Harvard Business Review* **69** (6): 96–104.
- O'Hara, L. A. & Sternberg, R. J. (1999). "Creativity and Intelligence". In ed. Sternberg, R. J.. *Handbook of Creativity*. Cambridge University Press.
- Pink, D. H. (2005). *A Whole New Mind: Moving from the information age into the conceptual age*. Allen & Unwin.
- Plucker, J. A. & Renzulli, J. S. (1999). "Psychometric Approaches to the Study of Human Creativity". In ed. Sternberg, R. J.. *Handbook of Creativity*. Cambridge University Press.
- Poincaré, H. (1908/1952). "Mathematical creation". In ed. Ghiselin, B.. *The Creative Process: A Symposium*. Mentor.
- Rhodes, M. (1961). "An analysis of creativity". *Phi Delta Kappan* **42**: 305–311.
- Rushton, J. P. (1990). "Creativity, intelligence, and psychoticism". *Personality and Individual Differences* **11**: 1291–1298. doi:10.1016/0191-8869(90)90156-L.
- Runco, M. A. (2004). "Creativity". *Annual Review of Psychology* **55**: 657–687. doi:10.1146/annurev.psych.55.090902.141502. PMID 14744230.
- Sabaneev, Leonid. The Psychology of the Musico-Creative Process // Psyche. - Vol. 9 (July 1928). - pp. 37-54.
- Smith, S. M. & Blakenship, S.E. (1 April 1991). "Incubation and the persistence of fixation in problem solving" (<http://jstor.org/stable/1422851>). *American Journal of Psychology* **104** (1): 61–87. doi:10.2307/1422851. ISSN 00029556. PMID 2058758.
- Taylor, C. W. (1988). "Various approaches to and definitions of creativity". In ed. Sternberg, R. J.. *The nature of creativity: Contemporary psychological perspectives*. Cambridge University Press.
- Torrance, E. P. (1974). *Torrance Tests of Creative Thinking*. Personnel Press.
- von Franz, Marie-Louise, *Psyche and Matter* (Shambhala, 1992) ISBN 0-87773-902-1
- Andersen, B., Korbo, L., & Pakkenberg, B. (1992). A quantitative study of the human cerebellum with unbiased stereological techniques. *The Journal of Comparative Neurology*, 326, 549-560.
- Imamizu, H., Kuroda, T., Miyauchi, S., Yoshioka, T. & Kawato, M. (2003). Modular organization of internal models of tools in the cerebellum. *Proceedings of the National Academy of Science*, 100, (9), 5461-5466.
- Jung-Beeman, M., Bowden, E., Haberman, J., Frymiare, J., Arambel-Liu, S., Greenblatt, R., Reber, P., & Kounios, J. (2004). Neural activity when people solve verbal problems with insight. *PLOS Biology*, 2, 500-510.
- Miller, E., & Cohen, J. (2001). An integrative theory of prefrontal cortex function. *Annual Review of Neuroscience*, 24, 167-202.
- Miyake, A., & Shah, P. (Eds.). (1999). *Models of working memory: Mechanisms of active maintenance and executive control*. New York: Cambridge University Press.
- Schmahmann, J. (Ed.). (1997). *The cerebellum and cognition*. New York: Academic Press.
- Schmahmann, J. (2004). Disorders of the cerebellum: Ataxia, dysmetria of thought, and the cerebellar cognitive affective syndrome. *Journal of Neuropsychiatry and Clinical Neuroscience*, 16, 367-378.
- Sullivan, Ceri and Graeme Harper, ed., *The Creative Environment: Authors at Work* (Cambridge: English Association/Boydell and Brewer, 2009)
- Vandervert, L. (2003a). How working memory and cognitive modeling functions of the cerebellum contribute to discoveries in mathematics. *New Ideas in Psychology*, 21, 159-175.
- Vandervert, L. (2003b). The neurophysiological basis of innovation. In L. V. Shavinina (Ed.) *The international handbook on innovation* (pp. 17–30). Oxford, England: Elsevier Science.



- Vandervert, L., Schimpf, P., & Liu, H. (2007). How working memory and the cerebellum collaborate to produce creativity and innovation [Special Issue]. *Creativity Research Journal*, 19(1), 1-19.
- DeGraff, J.; Lawrence, K. (2002). *Creativity at Work*. Jossey-Bass. ISBN 0787957259.

## Further reading

- Cropley, David H.; Cropley, Arthur J.; Kaufman, James C. et al., eds (2010). *The Dark Side of Creativity*. Cambridge: Cambridge University Press. ISBN 978-0-521-13960-1. Lay summary ([http://www.cambridge.org/gb/knowledge/isbn/item2704083/?site\\_locale=en\\_GB](http://www.cambridge.org/gb/knowledge/isbn/item2704083/?site_locale=en_GB)) (24 November 2010).
- Robinson, Andrew (2010). *Sudden Genius?: The Gradual Path to Creative Breakthroughs*. Oxford: Oxford University Press. ISBN 978-0-19-956995-3. Lay summary (<http://ukcatalogue.oup.com/product/9780199569953.do>) (24 November 2010).

# Ellis Paul Torrance

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**Ellis Paul Torrance** (October 8, 1915 - July 12, 2003) was an American psychologist from Milledgeville, Georgia.

After completing his undergraduate degree at Mercer University, he went on to complete a Master's degree at the University of Minnesota, and then a doctorate from the University of Michigan. His teaching career spanned from 1957 to 1984, first at the University of Minnesota and then later the University of Georgia, where he became professor of Educational Psychology in 1966.

In 1984, the University of Georgia established the Torrance Center for Creativity and Talent Development.

Torrance is best known for his research in creativity. His major accomplishments include 1,871 publications: 88 books; 256 parts of books or cooperative volumes; 408 journal articles; 538 reports, manuals, tests, etc.; 162 articles in popular journals or magazines; 355 conference papers; and 64 forewords or prefaces. He also created the Future Problem Solving Program International, the Incubation Curriculum Model, and the Torrance Tests of Creative Thinking.

## Torrance Tests of Creative Thinking (TTCT)

Building on J.P. Guilford's work, the Torrance Tests of Creative Thinking (TTCT) originally involved simple tests of divergent thinking and other problem-solving skills, which were scored on four scales:

- Fluency. The total number of interpretable, meaningful, and relevant ideas generated in response to the stimulus.
- Flexibility. The number of different categories of relevant responses.
- Originality. The statistical rarity of the responses.
- Elaboration. The amount of detail in the responses.

The third edition of the TTCT in 1984 eliminated the Flexibility scale from the figural test, but added Resistance to Premature Closure (based on Gestalt Psychology) and Abstractness of Titles as two new criterion referenced scores on the figural. Torrance called the new scoring procedure Streamlined Scoring. With the five norm-referenced measures that he now had (fluency, originality, abstractness of titles, elaboration and resistance to premature closure), he added 13 criterion referenced measures which include: emotional expressiveness, story-telling articulateness, movement or actions, expressiveness of titles, syntheses of incomplete figures, synthesis of lines, of circles, unusual visualization, extending or breaking boundaries, humor, richness of imagery, colourfulness of imagery, and fantasy.<sup>[1]</sup> According to Arasteh and Arasteh (1976) the most systematic assessment of creativity in elementary school children has been conducted by Torrance and his associates (1960a,1960b, 1960c, 1961,1962,1962a,1963a 1964), who have developed and administered the Minnesota Tests of Creative Thinking (MTCT) to several thousands of school children. Although they have used many of Guilford's concepts in their test

construction, the Minnesota group, in contrast to Guilford, has devised tasks which can be scored for several factors, involving both verbal and non-verbal aspects and relying on senses other than vision. These tests represent a fairly sharp departure from the factor type tests developed by Guilford and his associates (Guilford, Merrifield and Cox, 1961; Merrifield, Guilford and Gershan, 1963), and they also differ from the battery developed by Wallach and Kogan (1965), which contains measures representing creative tendencies that are similar in nature (Torrance, 1968).

To date, several longitudinal studies have been conducted to follow up the elementary school-aged students who were first administered the Torrance Tests in 1958 in Minnesota. There was a 22-year follow-up,<sup>[2] [3] [4]</sup> a 40-year follow-up<sup>[5]</sup>, and a 50 year follow-up<sup>[6]</sup>

Torrance (1962) grouped the different subtests of the Minnesota Tests of Creative Thinking (MTCT) into three categories.

1. Verbal tasks using verbal stimuli
2. Verbal tasks using non-verbal stimuli
3. Non-verbal tasks

A brief description of the tasks used by Torrance is given below:

### **Unusual Uses**

The unusual uses tasks using verbal stimuli are direct modifications of Guilford's Brick uses test. After preliminary tryouts, Torrance (1962) decided to substitute tin cans and books for bricks. It was believed the children would be able to handle tin cans and books more easily since both are more available to children than bricks.

#### Impossibilities task

It was used originally by Guilford and his associates (1951) as a measure of fluency involving complex restrictions and large potential. In a course in personality development and mental hygiene, Torrance has experimented with a number of modifications of the basic task, making the restrictions more specific. In this task the subjects are asked to list as many impossibilities as they can.

#### Consequences task

The consequences task was also used originally by Guilford and his associates (1951). Torrance has made several modifications in adapting it. He chose three improbable situations and the children were required to list out their consequences.

#### Just suppose task

It is an adaptation of the consequences type of test designed to elicit a higher degree of spontaneity and to be more effective with children. As in the consequence task, the subject is confronted with an improbable situation and asked to predict the possible outcomes from the introduction of a new or unknown variable.

#### Situations task

The situation task was modeled after Guilford's (1951) test designed to assess the ability to see what needs to be done. Subjects were given three common problems and asked to think of as many solutions to these problems as they can. For example, if all schools were abolished, what would you do to try to become educated?

#### Common problems task

This task is an adoption of Guilford's (1951) Test designed to assess the ability to see defects, needs and deficiencies and found to be one of the test of the factors termed sensitivity to problems. Subjects are instructed that they will be given common situations and that they will be asked to think of as many problems as they can that may arise in connection with these situations. For example, doing homework while going to school in the morning.

#### Improvement task

This test was adopted from Guilford's (1952) apparatus test which was designed to assess ability to see defects and all aspects of sensitivity to problems. In this task the subjects are given a list of common objects and are asked to suggest as many ways as they can to improve each object. They are asked not to bother about whether or not it is possible to implement the change thought of.

#### Mother- Hubbard problem

This task was conceived as an adoption of the situations task for oral administration in the primary grades and also useful for older groups. This test has stimulated a number of ideas concerning factors which inhibit the development of ideas.

#### Imaginative stories task

In this task the child is told to write the most interesting and exciting story he can think of. Topics are suggested (e.g., the dog that did not bark); or the child may use his own ideas.

#### Cow jumping problems

The Cow jumping problem is a companion task for the Mother- Hubbard problem and has been administered to the same groups under the same conditions and scored according to the similar procedures. The task is to think of all possible things which might have happened when the cow jumped over the moon.

### **Verbal tasks using nonverbal stimuli**

#### Ask and guess task

The ask and guess task requires the individual first to ask questions about a picture – questions which cannot be answered by just looking at the picture. Next he is asked to make guesses or formulate hypotheses about the possible causes of the event depicted, and then their consequences both immediate and remote.

#### Product improvement task

In this task common toys are used and children are asked to think of as many improvements as they can which would make the toy 'more fun to play with'. Subjects are then asked to think of unusual uses of these toys other than 'something to play with'.

#### Unusual uses task

In this task, along with the product improvement task another task (unusual uses) is used. The child is asked to think of the cleverest, most interesting and most unusual uses of the given toy, other than as a plaything. These uses could be for the toy as it is, or for the toy as changed.

### **Non-verbal tasks**

#### Incomplete figures task

It is an adaptation of the 'Drawing completion test' developed by Kate Franck and used by Barron (1958). On an ordinary white paper an area of fifty four square inches is divided into six squares each containing a different stimulus figure. The subjects are asked to sketch some novel objects or design by adding as many lines as they can to the six figures.

#### Picture construction task or shapes task

In this task the children are given shape of a triangle or a jelly bean and a sheet of white paper. The children are asked to think of a picture in which the given shape is an integral part. They should paste it wherever they want on the white sheet and add lines with pencil to make any novel picture. They have to think of a name for the picture and write it at the bottom.

#### Circles and squares task

It was originally designed as a nonverbal test of ideational fluency and flexibility, then modified in a such a way as to stress originality and elaboration. Two printed forms are used in the test. In one form, the subject is

confronted with a page of forty two circles and asked to sketch objects or pictures which have circles as a major part. In the alternate form, squares are used instead of circles.

#### Creative design task

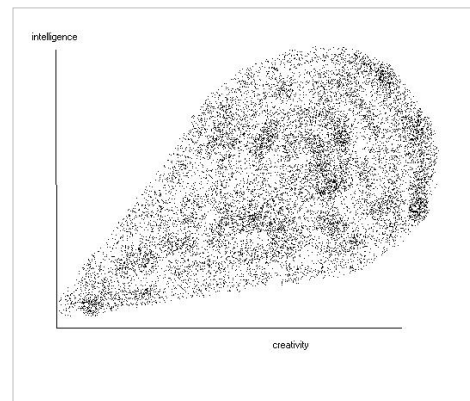
Hendrickson has designed it which seems to be promising, but scoring procedures are being tested but have not been perfected yet. The materials consist of circles and strips of various sizes and colours, a four page booklet, scissors and glue. Subjects are instructed to construct pictures or designs, making use of all of the coloured circles and strips with a thirty minute time limit. Subjects may use one, two, three, or four pages; alter the circles and strips or use them as they are; add other symbols with pencil or crayon.

## Threshold Hypothesis

There has been debate in the psychological literature about whether intelligence and creativity are part of the same process (the conjoint hypothesis) or represent distinct mental processes (the disjoint hypothesis).

Evidence from attempts to look at correlations between intelligence and creativity from the 1950s onwards, by authors such as Barron, Guilford or Wallach and Kogan, regularly suggested that correlations between these concepts were low enough to justify treating them as distinct concepts. Some researchers believe that creativity is the outcome of the same cognitive processes as intelligence, and is only judged as creativity in terms of its consequences, i.e., when the outcome of cognitive processes happens to produce something novel, a view which Perkins has termed the "nothing special" hypothesis.

A very popular model is what has come to be known as "the threshold hypothesis", proposed by Torrance, which holds that, in a general sample, there will be a positive correlation between low creativity and intelligence scores, but a correlation will not be found with higher scores. Research into the threshold hypothesis, however, has produced mixed results ranging from enthusiastic support to refutation and rejection.



## Biography

- Torrance, E.P. (1974). *Torrance Tests of Creative Thinking*. Scholastic Testing Service, Inc..
- Millar, G.W. (2007). *E. Paul Torrance, "The Creativity Man" : an Authorized Biography*. ISBN 1567501656.

## Bibliography

Professor Torrance authored of over 2,000 books, monographs, articles, reports, tests, manuals and instruction materials. (source: University of Minnesota Libraries <sup>[7]</sup>)

A special issue of *Creativity Research Journal* (guest edited by James C. Kaufman and John Baer) was dedicated to his honor and memory.

## References

- [1] Cramond, Bonnie (2002), *Critique on the Torrance Tests of Creative Thinking* ([http://kyunghee.myweb.uga.edu/portfolio/review\\_of\\_ttct.htm](http://kyunghee.myweb.uga.edu/portfolio/review_of_ttct.htm)),
- [2] (Torrance, E. P. (1980). Growing Up Creatively Gifted: The 22-Year Longitudinal Study. *The Creative Child and Adult Quarterly*, 3, 148-158.
- [3] Torrance, E. P. (1981a). Predicting the creativity of elementary school children (1958 80)and the teacher who "made a difference." *Gifted Child Quarterly*, 25, 55-62.

- [4] Torrance, E. P. (1981b). Empirical validation of criterionreferenced indicators of creative ability through a longitudinal study. *Creative Child and Adult Quarterly*, 6, 136-140.
- [5] Cramond, B., MatthewsMorgan, J., Bandalos, D., & Zuo, L. (2005). A report on the 40 year followup of the Torrance Tests of Creative Thinking: Alive and Well in the New Millennium. *Gifted Child Quarterly*, 49, 283-291.
- [6] Runco, M. A., Millar, G., Acar, S., Cramond, B. (2011) Torrance Tests of Creative Thinking as Predictors of Personal and Public Achievement: A Fifty Year Follow-Up. *Creativity Research Journal*, 22 (4). in press.
- [7] <http://special.lib.umn.edu/findaid/xml/uarc00790.xml>

## External links

- Torrance Center for Creativity and Talent Development (<http://www.coe.uga.edu/torrance/creativity-resources/>)

# Edward de Bono

**Edward de Bono** (born 19 May 1933, in Malta) is a physician, author, inventor, and consultant. He is known as the originator of the term lateral thinking, wrote a best selling book *Six Thinking Hats* and is a proponent of the deliberate teaching of thinking as a subject in schools.

## Biography

Edward de Bono studied at St Edward's College in Malta and gained a medical degree from the University of Malta. He was a Rhodes Scholar at Christ Church, Oxford where he gained an M.A. degree in psychology and physiology whilst being a keen sportsman; rowing and playing polo for Oxford. He also has a Ph.D. degree and a D.Phil. degree in Medicine from Cambridge University, a D.Des. degree (Doctor of Design) from the Royal Melbourne Institute of Technology, and an LL.D. degree from the University of Dundee.

He has held faculty appointments at the universities of Oxford, Cambridge, London and Harvard. He is a professor at Malta, Pretoria, Central England, and Dublin City University. de Bono holds the Da Vinci Professor of Thinking chair at University of Advancing Technology in Phoenix, USA.<sup>[1]</sup> He was one of the 27 Ambassadors for the European Year of Creativity and Innovation 2009.<sup>[2]</sup> He was nominated for the Nobel Prize for Economics in 2005.

He was formerly married, has two sons and resides in London.

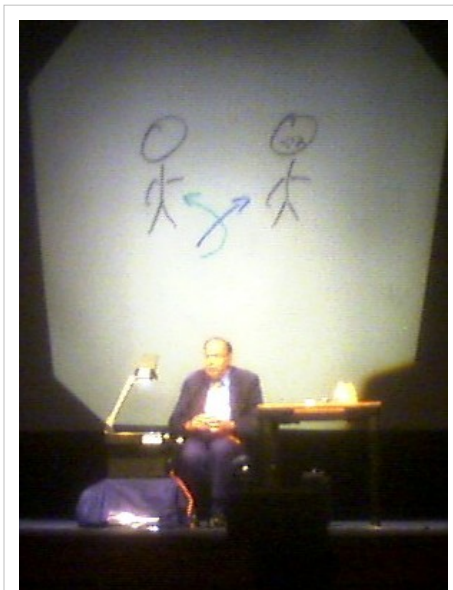
In 1969 de Bono founded the Cognitive Research Trust (CoRT) which continues to produce and promote material based on his ideas.

He has written 82 books with translations into 41 languages. He has taught his thinking methods to government agencies, corporate clients, organisations and individuals, privately or publicly in group sessions. He has started to set up the World Center for New Thinking, based in Malta, which he describes as a "kind of intellectual Red Cross".

In 1995, he created the futuristic documentary film, *2040: Possibilities by Edward de Bono*, a lecture designed to prepare an audience of viewers released from a cryogenic freeze for contemporary (2040) society.

De Bono has developed a range of 'deliberate thinking techniques' - which emphasise thinking as a deliberate act.

De Bono's techniques are used in companies like IBM, DuPont. Agencies offer corporate training courses based on his techniques think outside the box.



Edward de Bono

## Work

### Lateral Thinking

Edward de Bono's key concept is that logical, linear and critical thinking has limitations because it is based on argumentation. The traditional critical thinking processes of Plato, Aristotle and Socrates are reductive, designed to eliminate all but the truth. In many of de Bono's books, he calls for the more important need for creative thinking as a constructive way though that is deliberately designed. In de Bono's first book, *Mechanism of Mind*, he wrote of the importance to disrupt the dominant patterns preferred by human brain design to facilitate potential creative abilities. Many of de Bono's speculative models from that era about how the brain worked were vindicated by later brain research.

Lateral thinking, (literally, sideways thinking) uses various acts of provocation to incite ideas that are free from previously locked assumptions. The most well-known lateral thinking technique is the "random word." Invention of the word "PO" by de Bono, (meaning Provocative Operation, also related to POetry and hyPOthesis) gives notice that what will follow isn't meant as nonsense, but intended to relate to the subject at hand. Various provocative lateral thinking actions, (such as escape, new stimuli, reversal, etc.) were designed to deliberately shift perceptual assumptions for the purpose of generating observations and insights about the subject.

### Direct Teaching of Thinking

De Bono proposes that most of the problems in thinking are perceptual. Many more mistakes are made by jumping to the wrong conclusion too soon than by thinking irrationally once factors are known.

Edward de Bono held that "Operacy" is key, (another new word he has coined, related to literacy and numeracy.) Creativity should be producible on demand. Formation and design from new ideas cannot merely be left to chance. Because of these opinions, de Bono continues to invent ways to teach creative thinking as a separate skill. Former teaching strategies include complete courses that were adopted as curriculum for children, with later versions adapted for adults. This included many attention directing tools under the names of CoRT, later as DATT, Masterthinker series, and the most widely used Six Thinking Hats. He continues to experiment with new systems such as The de Bono Code.

All his thinking tools operate by directing attention to various aspects and factors of the topic at hand for a short time period of a few minutes. The various tools (with their corresponding acronyms) are often combined together in series to arrive at practical solutions.

For example, after making a list Considering All Factors, (CAF) the thinker selects a priority after doing a FIP (First Important Priorities.) Then, an OPV (Other Peoples' View) is used to help implementation of the idea. This tool prompts the thinker to list the people (or types of people) who would be affected by a proposed idea. The thinker is then required to imagine what effects that idea would have on each of these different people so their concerns may be anticipated and answered.

While this may sound like an exercise in altruism, it need not be. Say you've got a selfish desire (e.g. you're a kid wanting ice cream), then doing an OPV will help you anticipate and plan for other peoples' responses (e.g. "Mummy, me and Jimmy were thinking that cleaning our rooms to your complete satisfaction might earn us both an ice cream. But we would have to eat these ice-creams immediately to avoid spoiling our dinner, so we'd have to start cleaning right away.")

Schools from over twenty countries have included de Bono's thinking tools into their curriculum.<sup>[3]</sup>

## Language

De Bono has stated that he regards language as having been both the biggest help and the biggest barrier to human progress.

His contention is that just as language has allowed one generation to pass useful knowledge onto the next, it has also allowed dangerous myths and out-of-date ideas to become enshrined.

Convinced that a key way forward for humanity is better language, he published "The Edward de Bono Code Book" in 2000. In this book, he proposed a suite of new words based on numbers, where each number combination represents a useful idea or situation that currently does not have a single-word representation.

For example, de Bono code 6/2 means "Give me my point of view and I will give you your point of view." dBc 6/2 might be used in situations where one or both of two parties in a dispute are making insufficient effort to understand the other's perspective.<sup>[4]</sup>

## Ideas

In 2000, de Bono advised a U.K Foreign Office committee that the Arab-Israeli conflict might be due, in part, to low levels of zinc found in people who eat unleavened bread (i.e. pita flatbread), a known side-effect of which is aggression. He suggested shipping out jars of Marmite to compensate.<sup>[5] [6]</sup>

He has suggested an alternative to the penalty shootout when a soccer match ends in a draw. If the number of times each goalkeeper touches the ball is recorded throughout the game the results can be compared in the event of a draw. The team whose goalkeeper has touched the ball more often is the loser. The winner will then be the team that has had more attempts at scoring goals and is more aggressive (and therefore exciting) in their style of play. This mechanism would avoid the tension of the penalty shoot out. However, some people argue that this method of deciding a drawn match completely ignores the goalkeeper's skill which can win a game for a team. If the game goes to a penalty shootout, even though one team may have completely dominated the other, the goalkeeper has kept the scores level. Furthermore the goalkeeper can make highly skilled saves in a penalty shootout and defeat the better team.

Since poetry is an area of lateral thinking, he originated a form of poetry, similar to a limerick, that he termed a "Bonto." In 2007, his Septoe idea was given life through a new website. Septoes allow people to distill their wisdom into phrases of exactly seven words.<sup>[7]</sup>

## Games

Edward de Bono invented a simple game as a challenge, called the L Game, that requires strategy to win, and 'Concept Snap', which requires participants to think of ways in which different objects can be used to perform similar functions. He does contend that what is learned from games tends not to be transferred to thinking in real life.

## Critiques

The following two critiques on research methodology assume the Philosophy of Positivism. The critiques on Positivism usually comes from the Philosophy of Antipositivism.

1. In the *Handbook of Creativity*, Robert J. Sternberg writes, "Equally damaging to the scientific study of creativity, in our view, has been the takeover of the field, in the popular mind, by those who follow what might be referred to as a pragmatic approach. Those taking this approach have been concerned primarily with developing creativity, secondarily with understanding it, but almost not at all with testing the validity of their ideas about it." Sternberg continues, "Perhaps the foremost proponent of this approach is Edward De Bono, whose work on lateral thinking and other aspects of creativity has had what appears to be considerable commercial success."<sup>[8]</sup>
2. *Frameworks For Thinking* is an evaluation of 42 popular thinking frameworks conducted by a team of researchers. Regarding Edward De Bono they write, "[he] is more interested in the usefulness of developing ideas

than proving the reliability or efficacy of his approach. There is sparse research evidence to show that generalised improvements in thinking performance can be attributed to training in the use of CoRT or Thinking Hats tools. An early evaluation of CoRT reported significant benefits for Special Educational Needs (SEN) pupils.... However, in a more recent study with Australian aboriginal children (Ritchie and Edwards, 1996), little evidence of generalisation was found other than in the area of creative thinking."<sup>[9]</sup>

## Published works

Partial list of books by de Bono include:

- *The Use of Lateral Thinking* (1967) ISBN 0-14-013788-2, introduced the term "lateral thinking"
- *New Think* (1967, 1968) ISBN 0-380-01426-2
- *The Five-Day Course in Thinking* (1968), introduced the L game
- *The Mechanism of the Mind* (1969), Intl Center for Creative Thinking 1992 reprint: ISBN 0-14-013787-4, suggests that the mind is a pattern matching machine
- *Lateral Thinking: Creativity Step by Step*, (1970), Harper & Row 1973 paperback: ISBN 0-06-090325-2
- *The Dog-Exercising Machine* (1970)
- *Technology Today* (1971)
- *Practical Thinking* (1971)
- *Lateral Thinking for Management* (1971)
- *Po: A Device for Successful Thinking* (1972), ISBN 0-671-21338-5, introduced the term Po
- *Children Solve Problems* (1972) ISBN 13-978-0060110246, ISBN 10-0060110244
- *Po: Beyond Yes and No* (1973), ISBN 0-14-021715-0
- *Eureka!: An Illustrated History of Inventions from the Wheel to the Computer* (1974)
- *Teaching Thinking* (1976)
- *The Greatest Thinkers: The Thirty Minds That Shaped Our Civilization* (1976), ISBN 0-399-11762-8
- *Wordpower* (1977)
- *The Happiness Purpose* (1977)
- *Opportunities : A handbook for business opportunity search* (1978)
- *Future Positive* (1979)
- *Atlas of Management Thinking* (1981)
- *De Bono's Course in Thinking* (1982)
- *Learn-To-Think: Coursebook and Instructors Manual* with Michael Hewitt-Gleeson de Saint-Arnaud (1982), ISBN 0-88496-199-0
- *Tactics: The Art and Science of Success* (1985)
- *Conflicts: A Better Way to Resolve them* (1985)
- *Masterthinker's Handbook* (1985)
- *Six Thinking Hats* (1985) ISBN 0-316-17831-4
- *I Am Right, You Are Wrong: From This to the New Renaissance: From Rock Logic to Water Logic* (1990) ISBN 0-14-012678-3
- *Six Action Shoes* (1991)
- *Handbook for the Positive Revolution* (1991) ISBN 0-14-012679-1
- *Serious Creativity: Using the Power of Lateral Thinking to Create New Ideas* (1992) ISBN 0-00-255143-8 – a summation of many of De Bono's ideas on creativity
- *Sur/Petition* (1992) ISBN 0-88730-543-1 - creating value monopolies when everyone else is merely competing.
- *Parallel thinking: from Socratic thinking to de Bono thinking* (1994) ISBN 0670851264
- *Teach Yourself How to Think* (1995)
- *Textbook of Wisdom* (1996) ISBN 0670870110
- *How to Be More Interesting* (1998)



- *Simplicity* (1999)
- *New Thinking for the New Millennium* (1999)
- *Why I Want To Be King of Australia* (1999)
- *How to Have A Beautiful Mind* (2004)
- *Six Value Medals* (2005)
- *H+ (Plus): A New Religion* (2006)
- *How to Have Creative Ideas* (2007)
- *Free or Unfree? : Are Americans Really Free?* (2007) ISBN 1597775444
- *Six Frames For Thinking About Information* (2008)
- *Think! Before It's Too Late* (2009) ISBN 9780091924096

De Bono has also written numerous articles published in refereed and other journals, including *The Lancet* and *Clinical Science*.

## References

The Edward de Bono Society <sup>[10]</sup> is an information based and social networking site for all de Bono followers.

- [1] "About Edward de Bono" (<http://www.edwarddebono.com/about.htm>). Edward de Bono's Personal Web Site. 2008-05-05. . Retrieved 2008-05-05.
- [2] European Year of Creativity and Innovation 2009 - Europa (<http://create2009.europa.eu/ambassadors.html>), Europa.eu. Accessed 2009-05-14.
- [3] "About Edward de Bono" (<http://www.edwarddebono.com/about.htm>). Edward de Bono's Personal Web Site. 2008-05-05. . Retrieved 2008-05-05.
- [4] de Bono, Edward (2000). *The de Bono Code Book*. pp. 52.
- [5] Lloyd, J & Mitchinson, J: "The Book of General Ignorance". Faber & Faber, 2006.
- [6] Louise Jury: De Bono's Marmite plan for peace in Middle Yeast (<http://www.independent.co.uk/news/de-bonos-marmite-plan-for-peace-in-middle-yeast-1133338.html>), The Independent, 19 December 1999, retrieved 11 February 2009.
- [7] "Septoe Web Site" (<http://www.yourwisdom.ie>). Innovation Delivery. 2008-05-05. . Retrieved 2008-05-05.
- [8] Sternberg, R. J. & Lubart, T. L. (1999). "The Concept of Creativity", in ed. Sternberg, R. J.: *Handbook of Creativity*. Cambridge University Press.
- [9] Moseley, D., Baumfield, V., Elliott, J., Gregson, M., Higgins, S., Miller, J., Newton, D. (2005). "De Bono's lateral and parallel thinking tools", in ed. Moseley, David: *Frameworks for Thinking*. Cambridge University Press.
- [10] <http://www.debonosociety.com>

## Further reading

- Piers Dudgeon: *Breaking Out of the Box: The Biography of Edward de Bono*. London: Headline, 2001. ISBN 074726542X.

## External links

- Antonella Gambotto-Burke's interview with Edward de Bono (<http://www.theaustralian.com.au/news/features/the-thinker/story-e6frgabx-1225852743529>)
- de Bono web portal (<http://www.edwarddebono.com/>)
- Video interview on The Magazine Post (<http://www.themagazinepost.tv/default.php?idf=65>)
- de Bono social networking website (<http://www.debonosociety.com/>)

# Imagination

**Imagination**, also called the faculty of **imagining**, is the ability of forming mental images, sensations and concepts, in a moment when they are not perceived through sight, hearing or other senses. Imagination is the work of the mind that helps create. Imagination helps provide meaning to experience and understanding to knowledge; it is a fundamental faculty through which people make sense of the world,<sup>[1] [2] [3]</sup> and it also plays a key role in the learning process.<sup>[1] [4]</sup> A basic training for imagination is listening to storytelling (narrative),<sup>[1] [5]</sup> in which the exactness of the chosen words is the fundamental factor to "evoke worlds."<sup>[6]</sup>

It is accepted as the innate ability and process of inventing partial or complete personal realms within the mind from elements derived from sense perceptions of the shared world. The term is technically used in psychology for the process of reviving in the mind, percepts of objects formerly given in sense perception. Since this use of the term conflicts with that of ordinary language, some psychologists have preferred to describe this process as "imaging" or "imagery" or to speak of it as "reproductive" as opposed to "productive" or "constructive" imagination. Imagined images are seen with the "mind's eye."

Imagination can also be expressed through stories such as fairy tales or fantasies. Most famous inventions or entertainment products were created from the inspiration of someone's imagination.

Children often use narratives or pretend play in order to exercise their imagination. When children create fantasy they play at two levels: first, they use role playing to act out what they have created with their imagination, and at the second level they play again with their make-believe situation by acting as if what they have created is an actual reality that already exists in narrative myth.<sup>[7]</sup>

## Description

The common use of the term is for the process of forming new images in the mind that have not been previously experienced, or at least only partially or in different combinations. Some typical examples follow:

- Fairy tale
- Fiction
- A form of verisimilitude often invoked in fantasy and science fiction invites readers to pretend such stories are true by referring to objects of the mind such as fictional books or years that do not exist apart from an imaginary world.

Imagination in this sense, not being limited to the acquisition of exact knowledge by the requirements of practical necessity, is, up to a certain point, free from objective restraints. The ability to imagine one's self in another person's place is very important to social relations and understanding. Albert Einstein said, "Imagination ... is more important than knowledge. Knowledge is limited. Imagination encircles the world."<sup>[8]</sup>

In various spheres, however, even imagination is in practice limited: thus a person whose imaginations do violence to the elementary laws of thought, or to the necessary principles of practical possibility, or to the reasonable



Olin Levi Warner, *Imagination* (1896).  
Library of Congress Thomas Jefferson  
Building, Washington, D.C.

probabilities of a given case is regarded as insane.

The same limitations beset imagination in the field of scientific hypothesis. Progress in scientific research is due largely to provisional explanations which are constructed by imagination, but such hypotheses must be framed in relation to previously ascertained facts and in accordance with the principles of the particular science.

Imagination is an experimental partition of the mind used to create theories and ideas based on functions. Taking objects from real perceptions, the imagination uses complex IF-functions to create new or revised ideas. This part of the mind is vital to developing better and easier ways to accomplish old and new tasks. These experimental ideas can be safely conducted inside a virtual world and then, if the idea is probable and the function is true, the idea can be actualized in reality. Imagination is the key to new development of the mind and can be shared with others, progressing collectively.

Regarding the volunteer effort, imagination can be classified as:

- voluntary (the dream from the sleep, the daydream)
- involuntary (the reproductive imagination, the creative imagination, the dream of perspective)

## Psychology of imagination

Psychologists have studied imaginative thought, not only in its exotic form of creativity and artistic expression but also in its mundane form of everyday imagination.<sup>[9]</sup> Ruth M.J. Byrne has proposed that everyday imaginative thoughts about counterfactual alternatives to reality may be based on the same cognitive processes that rational thoughts are based on.<sup>[10]</sup> Children can engage in the creation of imaginative alternatives to reality from their very early years.<sup>[11]</sup>

## Imagination and Memory

Memory and imagination have been shown to be affected by one another, found through research in Priscilla Long's piece *My Brain On My Mind* "Images made by functional magnetic resonance imaging technology show that remembering and imagining sends blood to identical parts of the brain."<sup>[12]</sup> An optimal balance of intrinsic, extraneous, and germane form of information processing can heighten the chance of the brain to retain information as long term memories, rather than short term, memories. This is significant because experiences stored as long term memories are easier to be recalled, as they are ingrained deeper in the mind. Each of these forms require information to be taught in a specific manner so as to use various regions of the brain when being processed.<sup>[13]</sup> This information can potentially help develop programs for young students to cultivate or further enhance their creative abilities from a young age. The Neocortex and Thalamus are responsible for controlling the brain's imagination, along with many of the brain's other functions such as consciousness and abstract thought.<sup>[14]</sup> Since imagination involves many different brain functions, such as emotions, memory, thoughts etc., portions of the brain where multiple functions occur-- such as the Thalamus and Neocortex-- are the main regions where imaginative processing has been documented.<sup>[15]</sup> The understanding of *how* memory and imagination are linked in the brain, paves the way to better understand one's ability to link significant past experiences with their imagination.

## Imagination and perception

From the work of Piaget it is known that perceptions depend on the world view of a person. The world view is the result of arranging perceptions into existing imagery by imagination. Piaget cites the example of a child saying that the moon is following her when she walks around the village at night. Like this, perceptions are integrated into the world view to make sense. Imagination is needed to make sense of perceptions.<sup>[16]</sup>

## Imagination vs. belief

Imagination differs fundamentally from belief because the subject understands that what is personally invented by the mind does not necessarily impact the course of action taken in the apparently shared world, while beliefs are part of what one holds as truths about both the shared and personal worlds. The play of imagination, apart from the obvious limitations (e.g. of avoiding explicit self-contradiction), is conditioned only by the general trend of the mind at a given moment. Belief, on the other hand, is immediately related to practical activity: it is perfectly possible to imagine oneself a millionaire, but unless one believes it one does not, therefore, act as such. Belief endeavors to conform to the subject's experienced conditions or faith in the possibility of those conditions; whereas imagination as such is specifically free. The dividing line between imagination and belief varies widely in different stages of technological development. Thus in more extreme cases, someone from a primitive culture who ill frames an ideal reconstruction of the causes of his illness, and attributes it to the hostile magic of an enemy based on faith and tradition rather than science. In ignorance of the science of pathology the subject is satisfied with this explanation, and actually believes in it, sometimes to the point of death, due to what is known as the nocebo effect.

It follows that the learned distinction between imagination and belief depends in practice on religion, tradition, and culture.

## Imagination as a reality

The world as experienced is an interpretation of data arriving from the senses; as such, it is perceived as real by contrast to most thoughts and imaginings. Users of hallucinogenic drugs are said to have a heightened imagination. This difference is only one of degree and can be altered by several historic causes, namely changes to brain chemistry, hypnosis or other altered states of consciousness, meditation, many hallucinogenic drugs, and electricity applied directly to specific parts of the brain. The difference between imagined and perceived reality can be proven by psychosis. Many mental illnesses can be attributed to this inability to distinguish between the sensed and the internally created worlds. Some cultures and traditions even view the apparently shared world as an illusion of the mind as with the Buddhist maya, or go to the opposite extreme and accept the imagined and dreamed realms as of equal validity to the apparently shared world as the Australian Aborigines do with their concept of dreamtime.

Imagination, because of having freedom from external limitations, can often become a source of real pleasure and unnecessary suffering. Consistent with this idea, imagining pleasurable and fearful events is found to engage emotional circuits involved in emotional perception and experience.<sup>[17]</sup> A person of vivid imagination often suffers acutely from the imagined perils besetting friends, relatives, or even strangers such as celebrities. Also crippling fear can result from taking an imagined painful future too seriously.

Imagination can also produce some symptoms of real illnesses. In some cases, they can seem so "real" that specific physical manifestations occur such as rashes and bruises appearing on the skin, as though imagination had passed into belief or the events imagined were actually in progress. See, for example, psychosomatic illness and folie a deux.

It has also been proposed that the whole of human cognition is based upon imagination. That is, nothing that is perceived is purely observation but all is a morph between sense and imagination.

## Notes

- [1] Norman 2000 pp. 1-2
- [2] Brian Sutton-Smith 1988, p. 22
- [3] Archibald MacLeish 1970, p. 887
- [4] Kieran Egan 1992, pp. 50
- [5] Northrop Frye 1963, p. 49
- [6] As noted by Giovanni Pascoli
- [7] Laurence Goldman (1998). *Child's play: myth, mimesis and make-believe. Basically what this means is that the children use their make-believe situation and act as if what they are acting out is from a reality that already exists even though they have made it up.*. Berg Publishers. ISBN 1-85973-918-0.
- [8] Viereck, George Sylvester (October 26, 1929). "What life means to Einstein: an interview". *The Saturday Evening Post*.
- [9] Ward, T.B., Smith, S.M., & Vaid, J. (1997). *Creative thought*. Washington DC: APA
- [10] Byrne, R.M.J. (2005). *The Rational Imagination: How People Create Alternatives to Reality*. Cambridge, MA: MIT Press
- [11] Harris, P. (2000). *The work of the imagination*. London: Blackwell.
- [12] My Brain On My Mind p.27
- [13] Leahy, Wayne; John Sweller (5). "The Imagination Effect Increases with an Increased Intrinsic Cognitive Load". *Applied Cognitive Psychology* **22**: 275.
- [14] "Error: no ltitle= specified when using  {{{Template:Cite web|Cite web (http://www.brainhealthandpuzzles.com/brain\_parts\_function.html)}} }". Retrieved 3/05/2011.
- [15] "Error: no ltitle= specified when using  {{{Template:Cite web|Cite web (http://www.scienceforums.net/topic/33986-what-part-of-the-brain-handles-imagination-answered/)}} }". .
- [16] Piaget, J. (1967). *The child's conception of the world*. (J. & A. Tomlinson, Trans.). London: Routledge & Kegan Paul. BF721 .P5 1967X
- [17] Costa, VD, Lang, PJ, Sabatinelli, D, Bradley MM, and Versace, F (2010). "Emotional imagery: Assessing pleasure and arousal in the brain's reward circuitry". *Human Brain Mapping* **31** (9): 1446–1457. doi:10.1002/hbm.20948. PMID 20127869.

## External links

- Imagination (<http://www.bbc.co.uk/programmes/p005481c>) on In Our Time at the BBC. ( listen now ([http://www.bbc.co.uk/iplayer/console/p005481c/In\\_Our\\_Time\\_Imagination](http://www.bbc.co.uk/iplayer/console/p005481c/In_Our_Time_Imagination)))
- Imagination, Mental Imagery, Consciousness, and Cognition: Scientific, Philosophical and Historical Approaches (<http://www.imagery-imagination.com/>)
- Two-Factor Imagination Scale ([http://search.dmoz.org/cgi-bin/search?search=Two-Factor+Imagination+Scale&all=yes&cs=UTF-8&cat=Science/Social\\_Sciences/Psychology/Intelligence/Emotional\\_Intelligence/Online\\_Tests](http://search.dmoz.org/cgi-bin/search?search=Two-Factor+Imagination+Scale&all=yes&cs=UTF-8&cat=Science/Social_Sciences/Psychology/Intelligence/Emotional_Intelligence/Online_Tests)) at the Open Directory Project

## References

- Byrne, R.M.J. (2005). *The Rational Imagination: How People Create Alternatives to Reality*. Cambridge, MA: MIT Press
- Egan, Kieran (1992). *Imagination in Teaching and Learning*. Chicago: University of Chicago Press.
- Frye, N. (1963). *The Educated Imagination*. Toronto: Canadian Broadcasting Corporation.
- Norman, Ron (2000) *Cultivating Imagination in Adult Education* Proceedings of the 41st Annual Adult Education Research.
- Sutton-Smith, Brian. (1988). *In Search of the Imagination*. In K. Egan and D. Nadaner (Eds.), *Imagination and Education*. New York, Teachers College Press.
- Fabiani, Paolo "The Philosophy of the Imagination in Vico and Malebranche". F.U.P. (Florence UP), English edition 2009. (<http://www.fupress.com/Archivio/pdf/3622.pdf>) PDF

See also:

- Alice in wonderland
- Watkins, Mary: "Waking Dreams" [Harper Colophon Books, 1976] and "Invisible Guests - The Development of Imaginal Dialogues" [The Analytic Press, 1986]

- Moss, Robert: "The Three "Only" Things: Tapping the Power of Dreams, Coincidence, and Imagination" [New World Library, September 10, 2007]

Two philosophers for whom imagination is a central concept are John Sallis and Richard Kearney. See in particular:

- John Sallis, *Force of Imagination: The Sense of the Elemental* (2000)
- John Sallis, *Spacings-Of Reason and Imagination. In Texts of Kant, Fichte, Hegel* (1987)
- Richard Kearney, *The Wake of Imagination*. Minneapolis: University of Minnesota Press (1988); 1st Paperback Edition- (ISBN 0-8166-1714-7)
- Richard Kearney, "Poetics of Imagining: Modern to Post-modern." Fordham University Press (1998)

See also

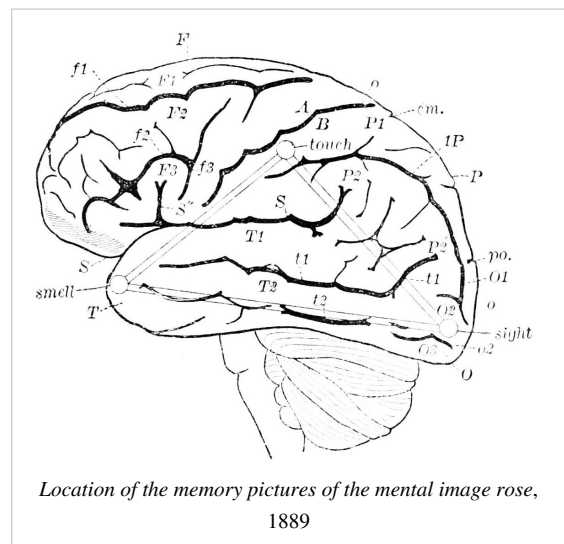
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## Mental image

A **mental image** is an experience that, on most occasions, significantly resembles the experience of perceiving some object, event, or scene, but occurs when the relevant object, event, or scene is not actually present to the senses.<sup>[1]</sup> <sup>[2]</sup> <sup>[3]</sup> <sup>[4]</sup> There are sometimes episodes, particularly on falling asleep (hypnagogic imagery) and waking up (hypnopompic), when the imagery, being of a rapid, phantasmagoric and involuntary character, defies perception, presenting a kaleidoscopic field, in which no distinct object can be discerned.<sup>[5]</sup>

The nature of these experiences, what makes them possible, and their function (if any) have long been subjects of research and controversy in philosophy, psychology, cognitive science, and more recently, neuroscience. As contemporary researchers use the expression, mental images (or *mental imagery*) can occur in the form of any sense, so that we may experience auditory images,<sup>[6]</sup> olfactory images,<sup>[7]</sup> and so forth. However, the vast majority of philosophical and scientific investigations of the topic focus upon *visual* mental imagery. It has been assumed that, like humans, many types of animals are capable of experiencing mental images.<sup>[8]</sup> Due to the fundamentally subjective nature of the phenomenon, there is little to no evidence either for or against this view.

Philosophers such as George Berkeley and David Hume, and early experimental psychologists such as Wilhelm Wundt and William James, understood ideas in general to be mental images, and today it is very widely believed that much imagery functions as mental representations (or mental models), playing an important role in memory and thinking.<sup>[9]</sup> <sup>[10]</sup> <sup>[11]</sup> <sup>[12]</sup> Some have gone so far as to suggest that images are best understood to be, by definition, a form of inner, mental or neural representation;<sup>[13]</sup> <sup>[14]</sup> in the case of hypnagogic and hypnapompic imagery, it is not representational at all. Others reject the view that the image experience may be identical with (or directly caused by) any such representation in the mind or the brain,<sup>[15]</sup> <sup>[16]</sup> <sup>[17]</sup> <sup>[18]</sup> <sup>[19]</sup> <sup>[20]</sup> but do not take account of the non-representational forms of imagery.



In 2010 IBM applied for a patent on how to extract mental images of human faces from the human brain.<sup>[21]</sup>

## How mental images form in the brain

Common examples of mental images include daydreaming and the mental visualization that occurs while reading a book. When a musician hears a song, he or she can sometimes "see" the song notes in their head, as well as hear them with all their tonal qualities.<sup>[22]</sup> This is considered different from an after-effect, such as an after-image. Calling up an image in our minds can be a voluntary act, so it can be characterized as being under various degrees of conscious control.

According to psychologist and cognitive scientist Steven Pinker,<sup>[23]</sup> our experiences of the world are represented in our minds as mental images. These mental images can then be associated and compared with others, and can be used to synthesize completely new images. In this view, mental images allow us to form useful theories of how the world works by formulating likely sequences of mental images in our heads without having to directly experience that outcome. Whether other creatures have this capability is debatable.

## Philosophical ideas about mental images

Mental images are an important topic in classical and modern philosophy, as they are central to the study of knowledge. In the *Republic*, book VII, Plato uses the metaphor of a prisoner in a cave, bound and unable to move, sitting with his back to a fire and watching the shadows cast on the wall in front of him by people carrying objects behind his back. The objects that they are carrying are representations of real things in the world. The prisoner, explains Socrates, is like a human being making mental images from the sense data that he experiences.

More recently, Bishop George Berkeley has proposed similar ideas in his theory of idealism. Berkeley stated that reality is equivalent to mental images — our mental images are not a copy of another material reality, but that reality itself. Berkeley, however, sharply distinguished between the images that he considered to constitute the external world, and the images of individual imagination. According to Berkeley, only the latter are considered "mental imagery" in the contemporary sense of the term.

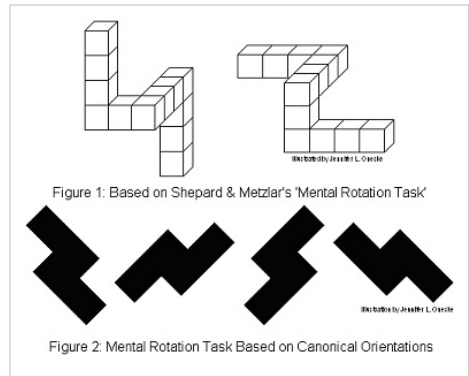
David Deutsch addresses Johnson's objection to idealism in *The Fabric of Reality* when he states that if we judge the value of our mental images of the world by the quality and quantity of the sense data that they can explain, then the most valuable mental image — or theory — that we currently have is that the world has a real independent existence and that humans have successfully evolved by building up and adapting patterns of mental images to explain it. This is an important idea in scientific thought.

Critics of scientific realism ask how the inner perception of mental images actually occurs. This is sometimes called the "homunculus problem" (see also the mind's eye). The problem is similar to asking how the images you see on a computer screen exist in the memory of the computer. To scientific materialism, mental images and the perception of them must be brain-states. According to critics, scientific realists cannot explain where the images and their perceiver exist in the brain. To use the analogy of the computer screen, these critics argue that cognitive science and psychology has been unsuccessful in identifying either the component in the brain (i.e. "hardware") or the mental processes that store these images (i.e. "software").

## Mental imagery in experimental psychology

Cognitive psychologists and (later) cognitive neuroscientists have empirically tested some of the philosophical questions related to whether and how the human brain uses mental imagery in cognition.

One theory of the mind that was examined in these experiments was the "brain as serial computer" philosophical metaphor of the 1970s. Psychologist Zenon Pylyshyn theorized that the human mind processes mental images by decomposing them into an underlying mathematical proposition. Roger Shepard and Jacqueline Metzler challenged that view by presenting subjects with 2D line drawings of groups of 3D block "objects" and asking them to determine whether that "object" was the same as a second figure, some of which were rotations of the first "object".<sup>[24]</sup> Shepard and Metzler proposed that if we decomposed and then mentally re-imagined the objects into basic mathematical



propositions, as the then-dominant view of cognition "as a serial digital computer"<sup>[25]</sup> assumed, then it would be expected that the time it took to determine whether the object was the same or not would be independent of how much the object was rotated. Shepard and Metzler found the opposite: a linear relationship between the degree of rotation in the mental imagery task and the time it took participants to reach their answer.

This mental rotation finding implied that the human mind — and the human brain — maintains and manipulates mental images as topographic and topological wholes, an implication that was quickly put to test by psychologists. Stephen Kosslyn and colleagues<sup>[26]</sup> showed in a series of neuroimaging experiments that the mental image of objects like the letter "F" are mapped, maintained and rotated as an image-like whole in areas of the human visual cortex. Moreover, Kosslyn's work showed that there were considerable similarities between the neural mappings for imagined stimuli and perceived stimuli. The authors of these studies concluded that while the neural processes they studied rely on mathematical and computational underpinnings, the brain also seems optimized to handle the sort of mathematics that constantly computes a series of topologically-based images rather than calculating a mathematical model of an object.

Recent studies in neurology and neuropsychology on mental imagery have further questioned the "mind as serial computer" theory, arguing instead that human mental imagery manifests both visually and kinesthetically. For example, several studies have provided evidence that people are slower at rotating line drawings of objects such as hands in directions incompatible with the joints of the human body,<sup>[27]</sup> and that patients with painful, injured arms are slower at mentally rotating line drawings of the hand from the side of the injured arm.<sup>[28]</sup>

Some psychologists, including Kosslyn, have argued that such results occur because of interference in the brain between distinct systems in the brain that process the visual and motor mental imagery. Subsequent neuroimaging studies<sup>[29]</sup> showed that the interference between the motor and visual imagery system could be induced by having participants physically handle actual 3D blocks glued together to form objects similar to those depicted in the line-drawings. Amorim et al. have recently shown that when a cylindrical "head" was added to Shepard and Metzler's line drawings of 3D block figures, participants were quicker and more accurate at solving mental rotation problems.<sup>[30]</sup> They argue that motoric embodiment is not just "interference" that inhibits visual mental imagery, but is capable of facilitating mental imagery.

These and numerous related studies have led to a relative consensus within cognitive science, psychology, neuroscience and philosophy on the neural status of mental images. Researchers generally agree that while there is no homunculus inside the head viewing these mental images, our brains do form and maintain mental images as image-like wholes.<sup>[31]</sup> The problem of exactly how these images are stored and manipulated within the human brain, particularly within language and communication, remains a fertile area of study.



One of the longest running research topics on the mental image has been the fact that people report large individual differences in the vividness of their images. Special questionnaires have been developed to assess such differences, including the Vividness of Visual Imagery Questionnaire (VVIQ) developed by David Marks. Laboratory studies have suggested that the subjectively reported variations in imagery vividness are associated with different neural states within the brain and also different cognitive competences such as the ability to accurately recall information presented in pictures<sup>[32]</sup> Rodway, Gillies and Schepman used a novel long-term change detection task to determine whether participants with low and high vividness scores on the VVIQ2 showed any performance differences.<sup>[33]</sup> Rodway et al. found that high vividness participants were significantly more accurate at detecting salient changes to pictures compared to low vividness participants.<sup>[34]</sup> This replicated an earlier study.<sup>[35]</sup>

Recent studies have found that individual differences in VVIQ scores can be used to predict changes in a person's brain while visualizing different activities.<sup>[36]</sup> Functional magnetic resonance imaging (fMRI) was used to study the association between early visual cortex activity relative to the whole brain while participants visualized themselves or another person bench pressing or stair climbing. Reported image vividness correlates significantly with the relative fMRI signal in the visual cortex. Thus individual differences in the vividness of visual imagery can be measured objectively.

## Training and learning styles

Some educational theorists have drawn from the idea of mental imagery in their studies of learning styles. Proponents of these theories state that people often have learning processes which emphasize visual, auditory, and kinesthetic systems of experience. According to these theorists, teaching in multiple overlapping sensory systems benefits learning, and they encourage teachers to use content and media that integrates well with the visual, auditory, and kinesthetic systems whenever possible.

Educational researchers have examined whether the experience of mental imagery affects the degree of learning. For example, imagining playing a 5-finger piano exercise (mental practice) resulted in a significant improvement in performance over no mental practice — though not as significant as that produced by physical practice. The authors of the study stated that "mental practice alone seems to be sufficient to promote the modulation of neural circuits involved in the early stages of motor skill learning."<sup>[37]</sup>

## Mental imagery, visualization and the Himalayan traditions

Vajrayana Buddhism, Bön and Tantra in general, utilize sophisticated visualization or *imaginal* (in the language of Jean Houston of Transpersonal Psychology) processes in the thoughtform construction of the yidam sadhana, kye-rim, and dzog-rim modes of meditation and in the yantra, thangka, and mandala traditions, where holding the fully realized form in the mind is a prerequisite prior to creating an 'authentic' new art work that will provide a sacred support or foundation for deity.<sup>[38] [39]</sup>

## References

- [1] McKellar, 1957
- [2] Richardson, 1969
- [3] Finke, 1989
- [4] Thomas, 2003
- [5] Wright, Edmond (1983). "Inspecting images". *Philosophy* **58** (223): 57-72 (see pp. 68-72).
- [6] Reisberg, 1992
- [7] Bensafi et al., 2003
- [8] Aristotle: *On the Soul* III.3 428a
- [9] Pavio, 1986
- [10] Egan, 1992
- [11] Barsalou, 1999
- [12] Prinz, 2002
- [13] Block, 1983
- [14] Kosslyn, 1983
- [15] Sartre, 1940
- [16] Ryle, 1949
- [17] Skinner, 1974
- [18] Thomas, 1999
- [19] Bartolomeo, 2002
- [20] Bennett & Hacker, 2003
- [21] IBM Patent Application (<http://www.freepatentsonline.com/20100049076.pdf>)
- [22] Sachs, Oliver (2007). *Musicophilia: Tales of Music and the Brain*. London: Picador. pp. 30–40.
- [23] Pinker, S. (1999). *How the Mind Works*. New York: Oxford University Press.
- [24] Shepard and Metzler 1971
- [25] Gardner 1987
- [26] Kosslyn 1995; see also 1994
- [27] Parsons 1987; 2003
- [28] Schwoebel et al. 2001
- [29] Kosslyn et al. 2001
- [30] Amorim et al. 2006
- [31] Rohrer 2006
- [32] Marks, 1973
- [33] Rodway, Gillies and Schepman 2006
- [34] Rodway et al. 2006
- [35] Gur and Hilgard 1975
- [36] Cui et al. 2007
- [37] Pascual-Leone et al. 1995
- [38] The Dalai Lama at MIT (<http://www.amazon.com/Dalai-Lama-at-MIT/dp/0674023196>) (2006)
- [39] Mental Imagery (<http://psychology.berkeley.edu/faculty/profiles/erosch2007-2.pdf>)

## Further reading

- Amorim, Michel-Ange, Brice Isableu and Mohammed Jarraya (2006) Embodied Spatial Transformations: "Body Analogy" for the Mental Rotation. *Journal of Experimental Psychology: General*.
- Barsalou, L.W. (1999). Perceptual Symbol Systems. (<http://www.bbsonline.org/documents/a/00/00/04/29/bbs00000429-00/bbs.barsalou.html>) *Behavioral and Brain Sciences* **22**: 577-660.
- Bartolomeo, P. (2002). The Relationship Between Visual perception and Visual Mental Imagery: A Reappraisal of the Neuropsychological Evidence. *Cortex* **38**: 357-378. *Cortex open access archive* (<http://www.cortex-online.org/cortex.asp?action=&from=home>)
- Bennett, M.R. & Hacker, P.M.S. (2003). *Philosophical Foundations of Neuroscience*. Oxford: Blackwell.
- Bensafi, M., Porter, J., Pouliot, S., Mainland, J., Johnson, B., Zelano, C., Young, N., Bremner, E., Aframian, D., Kahn, R., & Sobel, N. (2003). Olfactomotor Activity During Imagery Mimics that During Perception. *Nature Neuroscience* **6**: 1142-1144.
- Block, N. (1983). Mental Pictures and Cognitive Science. *Philosophical Review* **92**: 499-539.

- Cui, X., Jeter, C.B., Yang, D., Montague, P.R., & Eagleman, D.M. (2007). "Vividness of mental imagery: Individual variability can be measured objectively". *Vision Research*, 47, 474-478.
- Deutsch, David. *The Fabric of Reality*. ISBN 0-14-014690-3.
- Egan, Kieran (1992). *Imagination in Teaching and Learning*. Chicago: University of Chicago Press.
- Fichter, C. & Jonas, K. (2008). Image Effects of Newspapers. How Brand Images Change Consumers' Product Ratings. (<http://psycontent.metapress.com/content/35108m9705122820/>) *Zeitschrift für Psychologie / Journal of Psychology*, 216, 226-234.
- Finke, R.A. (1989). *Principles of Mental Imagery*. Cambridge, MA: MIT Press.
- Gardner, Howard. (1987) *The Mind's New Science: A History of the Cognitive Revolution* New York: Basic Books.
- Gur, R.C. & Hilgard, E.R. (1975). "Visual imagery and discrimination of differences between altered pictures simultaneously and successively presented". *British Journal of Psychology*, 66, 341-345.
- Kosslyn, Stephen M. (1983). *Ghosts in the Mind's Machine: Creating and Using Images in the Brain*. New York: Norton.
- Kosslyn, Stephen (1994) *Image and Brain: The Resolution of the Imagery Debate*. Cambridge, MA: MIT Press.
- Kosslyn, Stephen M., William L. Thompson, Irene J. Kim and Nathaniel M. Alpert (1995) Topographic representations of mental images in primary visual cortex. *Nature* 378: 496-8.
- Kosslyn, Stephen M., William L. Thompson, Mary J. Wraga and Nathaniel M. Alpert (2001) Imagining rotation by endogenous versus exogenous forces: Distinct neural mechanisms. *NeuroReport* 12, 2519–2525
- Marks, D.F. (1973). Visual imagery differences in the recall of pictures. *British Journal of Psychology*, 64, 17-24.
- Marks, D.F. (1995). New directions for mental imagery research. *Journal of Mental Imagery*, 19, 153-167.
- McGabhan, R., Squires, B, 2003, 'Releasing The Beast Within — A path to Mental Toughness', Granite Publishing, Australia.
- McKellar, Peter (1957). *Imagination and Thinking*. London: Cohen & West.
- Norman, Donald. *The Design of Everyday Things*. ISBN 0-465-06710-7.
- Paivio, Allan (1986). *Mental Representations: A Dual Coding Approach*. New York: Oxford University Press.
- Parsons, Lawrence M. (1987) Imagined spatial transformations of one's hands and feet. *Cognitive Psychology* 19: 178-241.
- Parsons, Lawrence M. (2003) Superior parietal cortices and varieties of mental rotation. *Trends in Cognitive Science* 7: 515-551.
- Pascual-Leone, Alvaro, Nguyet Dang, Leonardo G. Cohen, Joaquim P. Brasil-Neto, Angel Cammarota, and Mark Hallett (1995). Modulation of Muscle Responses Evoked by Transcranial Magnetic Stimulation During the Acquisition of New Fine Motor Skills. *Journal of Neuroscience* (<http://www.uth.tmc.edu/apstracts/1995/jn/May/158n.html>)
- Plato. *The Republic (New CUP translation into English)*. ISBN 0-521-48443-X.
- Plato. *Respublica (New CUP edition of Greek text)*. ISBN 0-19-924849-4.
- Prinz, J.J. (2002). *Furnishing the Mind: Concepts and their Perceptual Basis*. Boston, MA: MIT Press.
- Pylyshyn, Zenon W. (1973). What the mind's eye tells the mind's brain: a critique of mental imagery. *Psychological Bulletin* 80: 1-24
- Reisberg, Daniel (Ed.) (1992). *Auditory Imagery*. Hillsdale, NJ: Erlbaum.
- Richardson, A. (1969). *Mental Imagery*. London: Routledge & Kegan Paul.
- Rodway, P., Gillies, K. & Schepman, A. (2006). "Vivid imagers are better at detecting salient changes". *Journal of Individual Differences* 27: 218-228.
- Rohrer, T. (2006). The Body in Space: Dimensions of embodiment (<http://zakros.ucsd.edu/~trohrer/thebodyinspace.pdf>) The Body in Space: Embodiment, Experientialism and Linguistic Conceptualization]. In *Body, Language and Mind*, vol. 2. Zlatev, Jordan; Ziemke, Tom; Frank, Roz; Dirven, René (eds.). Berlin: Mouton de Gruyter, forthcoming 2006.

- Ryle, G. (1949). *The Concept of Mind*. London: Hutchinson.
- Sartre, J.-P. (1940). *The Psychology of Imagination*. (Translated from the French by B. Frechtman, New York: Philosophical Library, 1948.)
- Schwoebel, John, Robert Friedman, Nanci Duda and H. Branch Coslett (2001). Pain and the body schema evidence for peripheral effects on mental representations of movement. *Brain* 124: 2098-2104.
- Skinner, B.F. (1974). *About Behaviorism*. New York: Knopf.
- Shepard, Roger N. and Jacqueline Metzler (1971) Mental rotation of three-dimensional objects. *Science* 171: 701-703.
- Thomas, Nigel J.T. (1999). Are Theories of Imagery Theories of Imagination? An Active Perception Approach to Conscious Mental Content. (<http://www.imagery-imagination.com/im-im/im-im.htm>) *Cognitive Science* 23: 207-245.
- Thomas, N.J.T. (2003). Mental Imagery, Philosophical Issues About. (<http://www.imagery-imagination.com/mipia.htm>) In L. Nadel (Ed.), *Encyclopedia of Cognitive Science* (Volume 2, pp. 1147–1153). London: Nature Publishing/Macmillan.

## External links

- Mental Imagery (<http://plato.stanford.edu/entries/mental-imagery/>) in the *Stanford Encyclopedia of Philosophy* (<http://plato.stanford.edu/>)
  - Imagination, Mental Imagery, Consciousness, and Cognition: Scientific, Philosophical and Historical Approaches. (<http://www.imagery-imagination.com/>)
  - Roadmind University (<http://www.roadmind.com/use-of-the-roerich-psychodynamic-inventory-rpi/>) The Roerich Psychodynamic Inventory (RPI) provides statistical data to determine the validity of mental imagery for cognition of the minds raw emotional state. (Dr. Robert Roerich MD.)
  - Mental Imagery in Mathematics (<http://assoc.orange.fr/une.education.pour.demain/articlesrrr/mathematics/mlmente.htm>)
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# Convergent and divergent production

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**Convergent** and **divergent production** are the two types of human response to a set problem that were identified by J.P. Guilford (1967).

Guilford observed that most individuals display a preference for either convergent or divergent thinking. Others observe that most people prefer a convergent closure. As opposed to TRIZ or lateral thinking divergent thinking is not about tools for creativity or thinking, but a way of categorizing what can be observed.

## Divergent thinking

According to J.P. Guilford, divergent or "synthetic thinking" is the ability to draw on ideas from across disciplines and fields of inquiry to reach a deeper understanding of the world and one's place in it.

There is a movement in education that maintains divergent thinking might create more resourceful students. Rather than presenting a series of problems for rote memorization or resolution, divergent thinking presents open-ended problems and encourages students to develop their own solutions to problems.

Divergent production is the creative generation of multiple answers to a set problem. For example, *find uses for 1 meter lengths of black cotton*.

## Convergent thinking

Convergent thinking is oriented towards deriving the single best (or correct) answer to a clearly defined question. It emphasizes speed, accuracy, logic, and the like, and focuses on accumulating information, recognizing the familiar, reapplying set techniques, and preserving the already known. It is based on familiarity with what is already known (i.e., knowledge), and is most effective in situations where a ready-made answer exists and needs simply to be recalled from stored information, or worked out from what is already known by applying conventional and logical search, recognition and decision-making strategies.(OWAIS)

## Critic of the analytic/dialectic approach

While the observations made in psychology can be used to analyze the thinking of humans, such categories may also lead to oversimplifications and dialectic thinking.

The systematic use of convergent thinking may well lead to what is known as Group think—thus one should probably combine systematic use with critical thinking.

Categorizing thinkers as "divergent" or "convergent" may seem appropriate for the purpose of general analyses.

## References

- Guilford, J. (1967). The Nature of Human Intelligence.
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# Lateral thinking

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**Lateral thinking** is solving problems through an indirect and creative approach, using reasoning that is not immediately obvious and involving ideas that may not be obtainable by using only traditional step-by-step logic. The term *lateral thinking* was coined by Edward de Bono in the book *New Think: The Use of Lateral Thinking* published in 1967.

## Methods

Critical thinking is primarily concerned with judging the true value of statements and seeking errors. Lateral thinking is more concerned with the movement value of statements and ideas. A person would use lateral thinking when they want to move from one known idea to creating new ideas. Edward de Bono defines four types of thinking tools:

- Idea generating tools that are designed to break current thinking patterns—routine patterns, the status quo
- Focus tools that are designed to broaden where to search for new ideas
- Harvest tools that are designed to ensure more value is received from idea generating output
- Treatment tools that are designed to consider real-world constraints, resources, and support<sup>[1]</sup>

**Random Entry Idea Generating Tool:** Choose an object at random, or a noun from a dictionary, and associate that with the area you are thinking about.

For example imagine you are thinking about how to improve a web site. Choosing an object at random from an office you might see a fax machine. A fax machine transmits images over the phone to paper. Fax machines are becoming rare. People send faxes directly to phone numbers. Perhaps this could be a new way to embed the web site's content in emails and other sites.

**Provocation Idea Generating Tool:** choose to use any of the provocation techniques—wishful thinking, exaggeration, reversal, escape, or arising. Create a list of provocations and then use the most outlandish ones to move your thinking forward to new ideas.

**Challenge Idea Generating Tool:** A tool which is designed to ask the question "Why?" in a non-threatening way: why something exists, why it is done the way it is. The result is a very clear understanding of "Why?" which naturally leads to fresh new ideas. The goal is to be able to challenge anything at all, not just items which are problems.

For example you could challenge the handles on coffee cups. The reason for the handle seems to be that the cup is often too hot to hold directly. Perhaps coffee cups could be made with insulated finger grips, or there could be separate coffee cup holders similar to beer holders.

**Concept Fan Idea Generating Tool:** Ideas carry out concepts. This tool systematically expands the range and number of concepts in order to end up with a very broad range of ideas to consider.

**Disproving:** Based on the idea that the majority is always wrong (Henrik Ibsen, John Kenneth Galbraith), take anything that is obvious and generally accepted as "goes without saying", question it, take an opposite view, and try to convincingly disprove it.

The other focus, harvesting and treatment tools deal with the output of the generated ideas and the ways to use them.

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## Lateral thinking and problem solving

**Problem Solving:** When something creates a problem, the performance or the status quo of the situation drops. Problem solving deals with finding out what caused the problem and then figuring out ways to fix the problem. The objective is to get the situation to where it should be.

For example, a production line has an established run rate of 1000 items per hour. Suddenly, the run rate drops to 800 items per hour. Ideas as to why this happened and solutions to repair the production line must be thought of.

**Creative Problem Solving:** Using creativity, one must solve a problem in an indirect and unconventional manner.

For example, if a production line produced 1000 books per hour, creative problem solving could find ways to produce more books per hour, use the production line, or reduce the cost to run the production line.

**Creative Problem Identification:** Many of the greatest non-technological innovations are identified while realizing an improved process or design in everyday objects and tasks either by accidental chance or by studying and documenting real world experience....

## Further reading

- De Bono, Edward (1970). *Lateral thinking: creativity step by step* <sup>[2]</sup>. Harper & Row. pp. 300. ISBN 0-14-021978-1.
- De Bono, Edward (1972). *Po: Beyond Yes and No*. Penguin Books. ISBN 0-14-021715-0.
- De Bono, Edward (1992). *Serious creativity: using the power of lateral thinking to create new ideas* <sup>[3]</sup>. HarperBusiness. pp. 338. ISBN 0-88730-635-7.
- Sloane, Paul (1994). *Test your Lateral Thinking IQ* <sup>[4]</sup>. Sterling Publishing. pp. 96. ISBN 0-8069-0684-7.
- *The Leader's Guide to Lateral Thinking Skills*, Paul Sloane, (Kogan Page, 2006), ISBN 0-7494-4797-4

## References

[1] *Lateral Thinking: The Power of Provocation* manual: Published in 2006 by de Bono Thinking Systems

[2] <http://books.google.com/books?id=H-ROAAAAMAAJ>

[3] <http://books.google.com/books?id=NbB9AAAAMAAJ>

[4] <http://books.google.com/books?id=0op9AAAAMAAJ>

# Thinking outside the box

**Thinking outside the box** (sometimes erroneously called "thinking out of the box" or "thinking outside the square") is to think differently, unconventionally or from a new perspective. This phrase often refers to novel or creative thinking.

This is sometimes called a process of lateral thought. The catchphrase, or cliché, has become widely used in business environments, especially by management consultants and executive coaches, and has spawned a number of advertising slogans. To think outside the box is to look further and to try not thinking of the obvious things, but to try thinking beyond them.

## Analogy

A simplified definition for *paradigm* is a habit of reasoning or a conceptual framework.

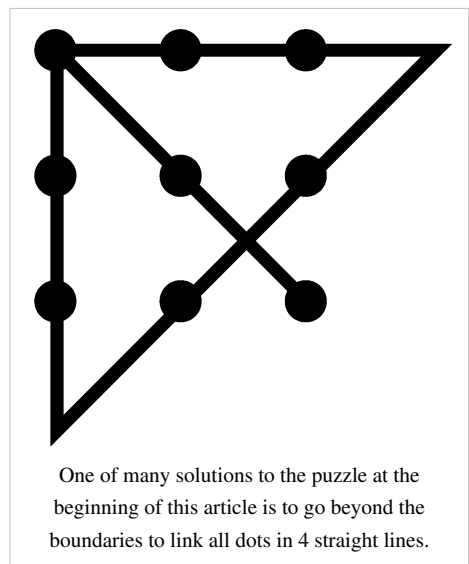
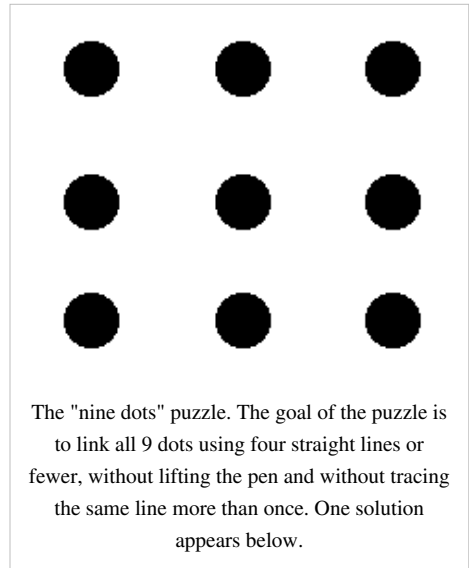
A simplified analogy is "the box" in the commonly used phrase "thinking outside the box". What is encompassed by the words "inside the box" is analogous with the current, and often unnoticed, assumptions about a situation. Creative thinking acknowledges and rejects the accepted paradigm to come up with new ideas.

## Nine dots puzzle

The notion of something outside a perceived "box" is related to a traditional topographical puzzle called the *nine dots puzzle*.<sup>[1]</sup>

The origins of the phrase "thinking outside the box" are obscure; but it was popularized in part because of a nine-dot puzzle, which John Adair claims to have introduced in 1969.<sup>[2]</sup> Management consultant Mike Vance has claimed that the use of the nine-dot puzzle in consultancy circles stems from the corporate culture of the Walt Disney Company, where the puzzle was used in-house.<sup>[3]</sup>

The puzzle proposed an intellectual challenge—to connect the dots by drawing four straight, continuous lines that pass through each of the nine dots, and never lifting the pencil from the paper. The conundrum is easily resolved, but only if you draw the lines outside the confines of the square area defined by the nine dots themselves. The phrase "thinking outside the box" is a restatement of the solution strategy. The puzzle only seems difficult because we imagine a boundary around the edge of the dot array.<sup>[4]</sup> The heart of the matter is the unspecified barrier which is typically perceived.





The nine dots puzzle is much older than the slogan. It appears in Sam Loyd's 1914 *Cyclopedia of Puzzles*.<sup>[5]</sup> In the 1951 compilation *The Puzzle-Mine: Puzzles Collected from the Works of the Late Henry Ernest Dudeney*, the puzzle is attributed to Dudeney himself.<sup>[6]</sup> Sam Loyd's original formulation of the puzzle<sup>[7]</sup> entitled it as "Christopher Columbus's egg puzzle." This was an allusion to the story of Egg of Columbus.

## Metaphor

This flexible English phrase is a rhetorical trope with a range of variant applications.

The metaphorical "box" in the phrase "outside the box" may be married with something real and measurable — for example, perceived budgetary<sup>[8]</sup> or organizational<sup>[9]</sup> constraints in a Hollywood development project. Speculating beyond its restrictive confines the box can be both:

- (a) positive— fostering creative leaps as in generating wild ideas (the conventional use of the term);<sup>[8]</sup> and
- (b) negative— penetrating through to the "bottom of the box." This could result in a frank and insightful re-appraisal of a situation, oneself, the organization, etc.<sup>[10]</sup>

On the other hand, the process of thinking "inside the box" need not be construed in a pejorative sense. It is crucial for accurately parsing and executing a variety of tasks — making decisions, analyzing data, and managing the progress of standard operating procedures, etc.<sup>[10]</sup>

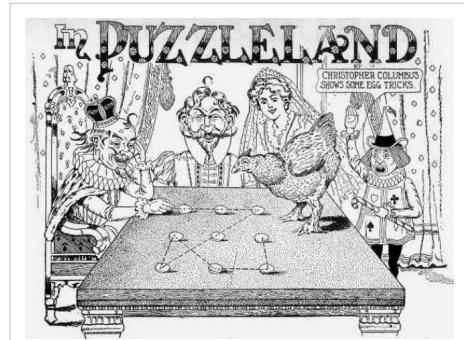
Hollywood screenwriter Ira Steven Behr appropriated this concept to inform plot and character in the context of a television series. Behr imagined a core character:

He is going to be "thinking outside the box," you know, and usually when we use that cliché, we think outside the box means a new thought. So we can situate ourselves back in the box, but in a somewhat better position<sup>[9]</sup>

The phrase can be used as a shorthand way to describe speculation about what happens next in a multi-stage design thinking process.<sup>[9]</sup>

## Notes

- [1] Kihn, Martin. "Outside the Box': the Inside Story," (<http://www.fastcompany.com/magazine/95/debunk.html>) *FastCompany* 1995; Random House: "Outside the Box Thinking" (<http://www.randomhouse.com/wotd/index.pperl?date=20000204>).
- [2] The Art of Creative Thinking: How to Be Innovative and Develop Great Ideas
- [3] Biography of Mike Vance (<http://www.creativethinkingassoc.com/mikevance.html>) at Creative Thinking Association of America.
- [4] Daniel Kies, "English Composition 2: Assumptions: Puzzle of the Nine Dots" (<http://papyr.com/hypertextbooks/comp2/9dots.htm>), retr. Jun. 28, 2009.
- [5] Sam Loyd, *Cyclopedia of Puzzles*. (The Lamb Publishing Company, 1914)
- [6] J. Travers, *The Puzzle-Mine: Puzzles Collected from the Works of the Late Henry Ernest Dudeney*. (Thos. Nelson, 1951)
- [7] Facsimile from *Cyclopedia of Puzzles* - Columbus's Egg Puzzle is on right-hand page (<http://www.mathpuzzle.com/loyd/cop300-301.html>)
- [8] Lupick, Travis. "Clone Wars proved a galactic task for production team." (<http://www.straight.com/article-158377/clone-wars-galactic-task>) *The Georgia Straight*, August 21, 2008; "... budgetary constraints forced the production team to think outside the box in a positive way."
- [9] TCA Tour – You Asked For It: Ira Steven Behr's opening remarks (<http://www.premiumhollywood.com/2009/08/03/tca-tour-you-asked-for-it-ira-steven-behrs-opening-remarks>)
- [10] Bandrowski, James F. et al. (2009). *Discover Your Inner Strength*, p. \_\_\_.



Christopher Columbus's Egg Puzzle as it appeared in Sam Loyd's *Cyclopedia of Puzzles*.

## References

- Bandrowski, James F.; Stephen R. Covey and Ken Blanchard. (2009). *Discover Your Inner Strength*. Sevierville, Tennessee: Insight Publishing. 10-ISBN 9781600132971/13-ISBN 1600132979; OCLC 320196099 (<http://www.worldcat.org/title/discover-your-inner-strength/oclc/320196099>)

## Further reading

- Adams, J. L. (1979). *Conceptual blockbusting: A guide to better ideas*. New York: W. W. Norton. ISBN 9780201100891. ISBN 0201100894 (more solutions to the nine dots problem - with less than 4 lines!)
- Scheerer, M. (1972). "Problem-solving". *Scientific American* **208** (4): 118–128.
- Golomb, Solom W.; Selfridge, John L. (1970). "Unicursal polygonal paths and other graphs on point lattices". *Pi Mu Epsilon Journal* **5**: 107–117. MR0268063.

## External links

- Out-of-the-box vs. outside the box ([http://www.phrases.org.uk/bulletin\\_board/29/messages/1149.html](http://www.phrases.org.uk/bulletin_board/29/messages/1149.html)) citing Oxford Advanced Learners Dictionary (OALD), Word of the Month

# Invention

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An **invention** is a new composition, device, or process. An invention may be derived from a pre-existing model or idea, or it could be independently conceived in which case it may be a radical breakthrough. In addition, there is **cultural invention**, which is an innovative set of useful social behaviors adopted by people and passed on to others.<sup>[1]</sup> Inventions often extend the boundaries of human knowledge or experience. An invention that is novel and not obvious to others skilled in the same field may be able to obtain the legal protection of a patent.

## Process

Invention is a creative process. An open and curious mind enables one to see beyond what is known. Seeing a new possibility, a new connection or relationship can spark an invention. Inventive thinking frequently involves combining concepts or elements from different realms that would not normally be put together. Sometimes inventors skip over the boundaries between distinctly separate territories or fields. Ways of thinking, materials, processes or tools from one realm are used as no one else has imagined in a different realm.

Play can lead to invention. Childhood curiosity like playing in a sand box, experimentation and imagination can develop one's play instinct—an inner need according to Carl Jung. Inventors feel the need to play with things that interest them, and to explore, and this internal drive brings about novel creations.<sup>[2]</sup> Thomas Edison: "I never did a day's work in my life, it was all fun". Inventing can also be an obsession.

To invent is to see anew. Inventors often envision a new idea, seeing it in their mind's eye. New ideas can arise when the conscious mind turns away from the subject or problem; or when the focus is on something else; or even while relaxing or sleeping. A novel idea may come in a flash - a Eureka! moment. For example, after years of working to figure out the general theory of relativity, the solution came to Einstein suddenly in a dream "like a giant die making an indelible impress, a huge map of the universe outlined itself in one clear vision".<sup>[3]</sup> Inventions can also be accidental, such as in the case of polytetrafluoroethylene (Teflon).

Insight is also a vital element of invention. It may begin with questions, doubt or a hunch. It may begin by recognizing that something unusual or accidental may be useful or that it could open a new avenue for exploration. For example, the odd metallic color of plastic made by accidentally adding a thousand times too much catalyst led scientists to explore its metal-like properties, inventing electrically conductive plastic and light emitting plastic—an

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invention that won the Nobel Prize in 2000 and has led to innovative lighting, display screens, wallpaper and much more (see conductive polymer, and organic light-emitting diode or OLED).<sup>[4]</sup>

Invention is often an exploratory process, with an outcome that is uncertain or unknown. There are failures as well as successes. Inspiration can start the process, but no matter how complete the initial idea, inventions typically have to be developed. Inventors believe in their ideas and they do not give up in the face of one or many failures. They are often famous for their perseverance, confidence and passion.

Inventors may, for example, try to improve something by making it more effective, healthier, faster, more efficient, easier to use, serve more purposes, longer lasting, cheaper, more ecologically friendly, or aesthetically different, e.g., lighter weight, more ergonomic, structurally different, with new light or color properties, etc.<sup>[5]</sup> Or an entirely new invention may be created such as the Internet, email, the telephone or electric light. Necessity may be the mother of invention, invention may be its own reward, or invention can create necessity. Nobody *needed* a phonograph before Edison invented it, the need for it developed afterward. Likewise, few ever imagined the telephone or the airplane prior to their invention, but many people cannot live without these inventions now.<sup>[6]</sup>

The idea for an invention may be developed on paper or on a computer, by writing or drawing, by trial and error, by making models, by experimenting, by testing and/or by making the invention in its whole form. As the dialogue between Picasso and Braque brought about Cubism, collaboration has spawned many inventions. Brainstorming can spark new ideas. Collaborative creative processes are frequently used by designers, architects and scientists. Co-inventors are frequently named on patents. Now it is easier than ever for people in different locations to collaborate. Many inventors keep records of their working process - notebooks, photos, etc., including Leonardo da Vinci, Thomas Jefferson and Albert Einstein.<sup>[7]</sup> In the process of developing an invention, the initial idea may change. The invention may become simpler, more practical, it may expand, or it may even *morph* into something totally different. Working on one invention can lead to others too. There is only one country in the world that will grant patent rights for an invention that continues part of an invention in a previously filed patent—the United States.<sup>[8]</sup>

The creation of an invention and its use can be affected by practical considerations. Some inventions are not created in the order that enables them to be most useful. For example, the parachute was invented before powered flight.<sup>[9]</sup> There are inventions that are too expensive to produce and inventions that require scientific advancements that have not yet occurred.<sup>[10]</sup> These barriers can erode or disappear as the economic situation changes or as science develops. But history shows that turning an invention that is only an idea into reality can take considerable time, even centuries as demonstrated by inventions originally conceived by Leonardo da Vinci which are now in physical form and commonplace in our lives.<sup>[11]</sup> Interestingly, some invention that exists as only an idea and has never been made in reality can obtain patent protection.<sup>[12]</sup>

An invention can serve many purposes, these purposes might differ significantly and they may change over time. An invention or a further developed version of it may serve purposes never envisioned by its original inventor(s) or even by others living at the time of its original invention. As an example, consider all the kinds of plastic developed, their innumerable uses, and the tremendous growth this material invention is still undergoing today.<sup>[13]</sup>

## Artistic invention

Invention has a long and important history in the arts. Inventive thinking has always played a vital role in the creative process. While some inventions in the arts are patentable, others are not because they cannot fulfill the strict requirements governments have established for granting them. (see patent).

## Art, design and architecture

"A man paints with his brain and not with his hands." - Michelangelo <sup>[14]</sup>

Art is continuously reinvented. Many artists, designers, and architects think like inventors. As they create, they may: explore beyond that which is known or obvious, push against barriers, change or discard conventions, and/or break into new territory. Breaking the rules became the most valued attribute in art during the 20th century, with the highest acclaim going to conceptual innovation which frequently involved the invention of new genres. For the first time the idea within the artwork was unmistakably more important than the tangible art object. All kinds of artists have been inventing throughout history, and among their inventions are important contributions to visual art and other fields.

Some visual artists like Picasso become inventors in the process of creating art. Inventions by other artists are separate from their art, such as the scientific inventions of Leonardo da Vinci. Some inventions in visual art employ prior developments in science or technology. For example, Picasso and Julio Gonzalez used welding to invent a new kind of sculpture, the form of which could be more open to light and air, and more recently, computer software has enabled an explosion of invention in visual art, including the invention of computer art, and invention in photography, film, architecture and design. Like the invention of welded sculpture, other inventions in art are new mediums, new art forms, or both. Examples are: the collage and the construction invented by Picasso, the Readymade invented by Marcel Duchamp, the mobile invented by Alexander Calder, the combine invented by Robert Rauschenberg, the shaped painting invented by Frank Stella, and the motion picture, the invention of which is attributed to Eadweard Muybridge.<sup>[15]</sup> Art has been reinvented by developing new processes of creation. For example, Jackson Pollock invented an entirely new form of painting and a new kind of abstraction by dripping, pouring, splashing and splattering paint onto unstretched canvas laying on the floor. A number of art movements were inventions often created collaboratively, such as Cubism invented by Picasso and Braque. Substantial inventions in art, design and architecture were made possible by inventions and improvements in the tools of the trade. The invention of Impressionist painting, for example, was possible because the prior invention of collapsible, resealable metal paint tubes facilitated spontaneous painting outdoors. Inventions originally created in the form of artwork can also develop other uses, as Alexander Calder's mobile is commonly used over babies' cribs today. Funds generated from patents on inventions in art, design and architecture can support the realization of the invention or other creative work. Frederic Auguste Bartholdi's 1879 patent on the Statue of Liberty helped fund the statue currently in New York harbor because it covered small replicas.<sup>[16]</sup>

Among other artists, designers and architects who are or were inventors are: Filippo Brunelleschi, Le Corbusier, Naum Gabo, Frederick Hart, Louis Comfort Tiffany, John La Farge, Buckminster Fuller, Walt Disney, Man Ray, Yves Klein, Henry N. Cobb, I. M. Pei, Kenneth Snelson, Helen Frankenthaler, Chuck (Charles) Hoberman and Ingo Maurer. Some of their inventions have been patented. Others might have fulfilled the requirements of a patent, like the Cubist image. There are also inventions in visual art that do not fit into the requirements of a patent. Examples are inventions that cannot be differentiated from that which has already existed clearly enough for approval by government patent offices, such as Duchamp's Readymade and other conceptual works. Invention whose inventor or inventors are not known cannot be patented, such as the invention of abstract art or abstract painting, oil painting, Process Art, Installation art and Light Art. Also, when it cannot or has not been determined whether something was a first in human history or not, there may not be a patentable invention even though it may be considered an invention in the realm of art. For example, Picasso is credited with inventing collage though this was done earlier in cultures outside of the western world.

Inventions in the visual arts that may be patentable might be new materials or mediums, new kinds of images, new processes, novel designs, or they may be a combination of these. Inventions by Filippo Brunelleschi, Frederick Hart, Louis Comfort Tiffany, John La Farge, Walt Disney, Henry N. Cobb, Chuck (Charles) Hoberman and others received patents. The color, International Klein Blue invented by Yves Klein was patented in 1960 and used two years later in his sculpture. Inventions by Kenneth Snelson which are crucial to his sculptures are patented. R. Buckminster Fuller's famous geodesic dome is covered in one of his 28 US patents. Ingo Maurer known for his lighting design has a series of patents on inventions in these works. Many inventions created collaboratively by designers at IDEO Inc. have been patented. Countless other examples can easily be found by searching patents at the websites of the Patent Offices of various countries, such as <http://www.USPTO.gov>. Inventions in design can be protected in a special kind of patent called a "design patent". The first design patent was granted in 1842 to George Bruce for a new font.<sup>[17]</sup> See a database of patents in the arts at <http://www.patenting-art.com/database/dbase1-e.htm>. See images and text from some patents in the arts at <http://www.patenting-art.com/images/images-e.htm>.  
[18] [19] [20]

The steps of inventing go as follows:

1. 1 Idea: any random person can get an idea. Sometimes they are not the best ideas, but others could change the world.
2. 2 Record: writing your idea down.
3. 3 Diagram: adding drawings and explanations.
4. 4 Plan: Figure out how to create your idea.
5. 5 Create:

## Music

Music has been expanded by invention over the course of thousands of years.

**Timeline** - *dates may be approximations*

5000 BCE - The first flutes were made in India out of wood.

3000 BCE - The first string instrument, the guqin was invented in China.

619 - The orchestra was invented in the Chinese royal courts with hundreds of musicians.

855 - Polyphonic music was invented.

910 - The musical score was invented by the musician, Hucbaldus. He also invented a staff that had an indefinite number of lines.

1025 - Musical notes were invented by Guido of Arezzo, named UT, RE, MI, FA, SO and LA. Later in the 16th century UT was changed to DO and TI was added. Lines/staves to space printed notes were added then too.

1225 - Rounds, songs sung in harmony, were invented with the song, *Sumer is icumen in* by John of Fornsete, an English monk.

1607 - A tonal system that gave the recitative a more flexible accompaniment was invented, revolutionizing music in the first opera masterpiece, *Orfeo*, by Claudio Monteverdi, a composer, musician and singer.

1696 - The metronome, a device for beating time was invented by Etienne Loulie, a musician, pedagogue and musical theorist.<sup>[21]</sup>

1698-1708 - The piano was invented by Bartolomeo Cristofori<sup>[22]</sup>

1787 - Algorithmic music was invented by Amadeus Mozart with his *Musikalisches Würfelspiel*.

1829 - The accordion, a portable reed instrument was invented by Damian.

1835 - The tuba<sup>[23]</sup> proper was first patented by Prussian bandmaster Wilhelm Wieprecht and German instrument-builder Johann Gottfried Moritz.

1841 - The saxophone was invented by Adolphe Sax, an instrument maker.

1880 - Tango music was invented by the Argentinians, combining African, Indian and Spanish rhythms.

1919 - The first electronic music instrument, the theremin was invented by Lev Theremin. It is played by moving hands near an antenna.

1922 - *Muzak*, engineered music without vocals, tempo changes or brass instruments was invented by Brig. General George Owen Squier.<sup>[24]</sup>

1932 - The electric guitar, the Frying pan was invented by George Beauchamp

1953 - *Rock and Roll* was invented by the musician, Bill Haley with *Crazy Man Crazy* combining guitars, saxophones, piano, bass, and snare drums, who was imitating African American musicians such as Chuck Berry.

1957 - Computer-assisted musical composition was invented with *Illiac Suite for String Quartet* by scientists at the University of Illinois in Urbana.<sup>[25]</sup>

1964 - The Moog Synthesizer was invented by Robert Moog.<sup>[26]</sup>

1974 - The Chapman Stick was invented by Emmett Chapman.

## Literature

Literature has been reinvented throughout history.

**Timeline** - *dates may be approximations*

1950 BC - The novel was invented with a narrative form. This was *Story of Sinuhe* about a prince of Egypt who flees after a court killing, is saved in the desert by a Bedouin tribe, and marries the eldest daughter of a king. Some people see *Story of Sinuhe* as the precursor of the story of Moses in the Bible.

675 BC - The heroic ballad was invented by Stesichorus of Sicily.

553 - Scandal literature was invented by Procopius in *Anecdota*.

808 - Copying written works by printing was invented by the Chinese who created *The Diamond Sutra* a seven page paper scroll, printed with woodblocks.

1022 - The romance novel was invented by Murasaki Shikibu, a Japanese noblewoman who wrote *Genji the Shining One*.

1657 - The science fiction novel was invented by Savinien Cyrano de Bergerac who wrote *Les etas et empires de la lune* about a trip to the moon.

1816 - Literary horror was invented by Mary Shelley who wrote *Frankenstein*.

1843 - The mystery novel was invented by Edgar Allan Poe who wrote "The Gold-Bug".

1857 - Writing in which the author conceals a single narrator's perspective and uses multiple other points of view was first done by Gustav Flaubert in *Madame Bovary*.

1895 - The serial comic strip was invented by the publisher, Joseph Pulitzer with *The Yellow Kid*, in the New World Newspaper.<sup>[27]</sup>

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## Performing arts

The value of invention in acting was noted by Paul Newman when retiring, "You start to lose your memory, your confidence, your invention. So that's pretty much a closed book for me".<sup>[28]</sup>

Works by Martha Graham and many other artists known for invention.<sup>[29]</sup>

**Timeline** - *dates may be approximations*

450 BCE - Mime was invented by Sophron of Syracuse.

1597 - Opera was invented by Jacopo Peri with *Dafne*. Peri was an Italian composer and singer.

1780 - Bolero dance was invented by Sebastiano Carezo, a Spanish dancer.

1833 - Minstrel shows were invented by Thomas Dartmouth "Daddy" Rice.

1880 - Tango dance was invented by the Argentinians, combining African, Indian and Spanish rhythms.

1922 - Radio drama was invented as Eugene Walter's play, *The Wolf* was broadcast by WGY, a station in Schenectady, New York. WGY later created a whole radio show, *The WGY Players* that presented radio adaptations of popular plays.<sup>[30]</sup>

1993 - a system that allows the wearer of specially designed shoes to lean forward beyond his center of gravity and appear to defy gravity was invented and patented by Michael Jackson, Michael Bush, and Dennis Tompkins. Michael Jackson used it in performances. Refer to US Patent No. 5,255,452.

## Implementation

Inventions get out into the world in different ways. Some are sold, licensed or given away as products or services. Simply exhibiting visual art, playing music or having a performance gets many artistic inventions out into the world. Believing in the success of an invention can involve risk, so it can be difficult to obtain support and funding. Grants, inventor associations, clubs and business incubators can provide the mentoring, skills and resources some inventors need. Success at getting an invention out into the world often requires passion for it and good entrepreneurial skills.<sup>[31]</sup>

In economic theory, inventions are one of the chief examples of "positive externalities", a beneficial side-effect that falls on those outside a transaction or activity. One of the central concepts of economics is that externalities should be internalized—unless some of the benefits of this positive externality can be captured by the parties, the parties will be under-rewarded for their inventions, and systematic under-rewarding will lead to under-investment in activities that lead to inventions. The patent system captures those positive externalities for the inventor or other patent owner, so that the economy as a whole will invest a more-closely-optimum amount of resources in the process of invention.

## Invention in patent law

The legal invention concept is central in patent law. As is often the case for legal concepts, its meaning is slightly different from common parlance meaning. A further complication is that the invention concept is quite different in American and European patent law.

In Europe, the first test patent applications are submitted to is: "is this an invention"? If it is, subsequent questions to be answered are whether it is new, and sufficiently inventive. The implication - rather counterintuitively - is that a legal invention is not inherently novel. Whether a patent application relates to an invention is governed by Article 52 of the European Patent Convention, that excludes e.g. discoveries *as such* and software *as such*. The EPO Boards of Appeal have decided that the technical character of an application is decisive for it to be an invention, following an age-old German tradition. British courts don't agree with this interpretation. Following a 1959 Australian decision ("NRDC"), they believe that it is not possible to grasp the invention concept in a single rule. A British court once stated that the technical character test implies a "restatement of the problem in more imprecise terminology".

In the United States, all patent applications are considered inventions. The statute explicitly says that the American invention concept includes discoveries (35 USC § 100(a)), contrary to the European invention concept. The European invention concept corresponds to the American "patentable subject matter" concept: the first test a patent application is submitted to. While the statute (35 USC § 101) virtually poses no limits to patenting whatsoever, courts have decided in binding precedents that abstract ideas, natural phenomena and laws of nature are not patentable. Various attempts were made to substantiate the "abstract idea" test, which suffers from abstractness itself, but eventually none of them was successful. The last attempt so far was the "machine or transformation" test, but the U.S. Supreme Court decided in 2010 that it is merely an indication at best.

## Invention and innovation

In the social sciences, an innovation is anything new to a culture, whether it has been adopted or not. The theory for adoption (or non-adoption) of an innovation, called diffusion of innovations, considers the likelihood that an innovation will ever be adopted and the taxonomy of persons likely to adopt it or spur its adoption. This theory was first put forth by Everett Rogers.<sup>[32]</sup> Gabriel Tarde also dealt with the adoption of innovations in his *Laws of Imitation*.<sup>[33]</sup>

## Notes

- [1] Artificial Mythologies: A Guide to Cultural Invention by Craig J. Saper (1997); Review of Artificial Mythologies. A Guide to cultural Invention, Kirsten Ostherr (1998) [http://findarticles.com/p/articles/mi\\_qa3709/is\\_199810/ai\\_n8821092](http://findarticles.com/p/articles/mi_qa3709/is_199810/ai_n8821092)
- [2] The Lemelson Center's website, Invention at Play: Inventors' Stories, [http://www.inventionatplay.org/inventors\\_main.html](http://www.inventionatplay.org/inventors_main.html); and Juice: The Creative Fuel That Drives World-Class Inventors (2004), p.14-15 by Evan I. Schwartz.
- [3] Einstein: A Life by Denis Brian p.159 (1996)
- [4] Nobelprize.org, *The Nobel Prize in Chemistry 2000* ([http://nobelprize.org/nobel\\_prizes/chemistry/laureates/2000/public.html](http://nobelprize.org/nobel_prizes/chemistry/laureates/2000/public.html))
- [5] Countless examples can easily be found by searching patents, such as on <http://patft.uspto.gov/netahtml/PTO/search-bool.html>
- [6] Forks, Phonographs, and Hot Air Balloons: A Field Guide to Inventive Thinking p. 8 (1992), by Robert J. Weber, also from Juice: The Creative Fuel That Drives World-Class Inventors, p. 13 (2004) by Evan I. Schwartz
- [7] The Inventor's Notebook by Fred Grissom and David Pressman (2005); Leonardo da Vinci: Artist, Scientist, Inventor by Simona Cremante (2005), [http://memory.loc.gov/ammem/collections/jefferson\\_papers/](http://memory.loc.gov/ammem/collections/jefferson_papers/); <http://www.alberteinstein.info/about/>
- [8] [http://www.uspto.gov/web/offices/pac/mpep/documents/0200\\_201\\_08.htm](http://www.uspto.gov/web/offices/pac/mpep/documents/0200_201_08.htm)
- [9] White, Lynn: The Invention of the Parachute, *Technology and Culture*, Vol. 9, No. 3, (Jul., 1968), pp. 462-467
- [10] See US Patent #5,461,114 and D11,023 as well as Leonardo da Vinci: Artist, Scientist, Inventor by Simona Cremante (2005)
- [11] Leonardo da Vinci: Artist, Scientist, Inventor by Simona Cremante (2005)
- [12] Patent It Yourself by David Pressman (2000), particularly section 9/2, as a specific example refer to 1879, F. Auguste Bartholdi U.S. Patent D11,023
- [13] Most information is directly from the Smithsonian Institution's Lemelson Center for Invention and Innovation, <http://www.invention.smithsonian.org/home/>, e.g., Invention at Play: Inventors' Stories, [http://www.inventionatplay.org/inventors\\_main.html](http://www.inventionatplay.org/inventors_main.html) and Juice: The Creative Fuel That Drives World-Class Inventors (2004) by Evan I. Schwartz (download an interview with this author about his book at <http://www.npr.org/templates/story/story.php?storyId=4244179>). Also: Notebooks of the Mind: Explorations of Thinking (1985) by Vera John-Steiner; <http://www.greenfieldpatents.com/inventiveprocess.php>; <http://www.uspto.gov>, <http://www.uspto.gov/main/glossary/index.html#cip>; American Heritage.com article "How Did the Heroic Inventors Do It?" by Thomas P. Hughes at [http://www.americanheritage.com/articles/magazine/it/1985/2/1985\\_2\\_18.shtml](http://www.americanheritage.com/articles/magazine/it/1985/2/1985_2_18.shtml); History of Plastics and Plastic Packaging Products — Polyethylene, Polypropylene, and More <http://www.packagingtoday.com/introplasticexplosion.htm>; A directory of resins from 600 plastics manufacturers <http://www.ides.com/plastics/A.htm> Plastics Materials; Detailed Guide To All Plastics Processes, British Plastics Federation [http://www.bpf.co.uk/bpfindustry/process\\_plastics.cfm](http://www.bpf.co.uk/bpfindustry/process_plastics.cfm); <http://www.plastiquarian.com/Plastics Historical Society>; History of plastics, Society of the Plastics Industry <http://www.plasticsindustry.org/industry/history.htm>
- [14] Finding quotations was never this easy ([http://thinkexist.com/search/searchquotation.asp?search=brain&q=author:"Michelangelo"](http://thinkexist.com/search/searchquotation.asp?search=brain&q=author:))
- [15] [www.encyclopedia.com/topic/Eadweard\\_Muybridge.aspx#1E1-Muybridg](http://www.encyclopedia.com/topic/Eadweard_Muybridge.aspx#1E1-Muybridg), and see [www.britannica.com/EBchecked/topic/399928/Eadweard-Muybridge](http://www.britannica.com/EBchecked/topic/399928/Eadweard-Muybridge)
- [16] 1879, F. Auguste Bartholdi U.S. Patent D11,023
- [17] <http://www.ipwatchdog.com/2008/11/06/the-first-design-patent-2/id=242/>
- [18] "A Textbook Example of Ranking Artworks" by Patricia Cohen, *The New York Times*, (08-04-08)
- [19] *Picasso and the Invention of Cubism* by Pepe Karmel (2003)
- [20] *Leonardo da Vinci: Artist, Scientist, Inventor* by Simona Cremante (2005)
- [21] Patenting Art and Entertainment by Gregory Aharonian and Richard Stim



- [22] <http://www.timelineindex.com/content/view/1477>
- [23] <http://www.blackdiamondbrass.com/tbahist/tubahist.htm>
- [24] Patenting Art and Entertainment by Gregory Aharonian and Richard Stim
- [25] Patenting Art and Entertainment by Gregory Aharonian and Richard Stim
- [26] <http://120years.net/machines/moog/>
- [27] Patenting Art and Entertainment by Gregory Aharonian and Richard Stim
- [28] "Newman says he's done with acting" ([http://www.boston.com/news/globe/living/articles/2007/05/26/newman\\_says\\_hes\\_done\\_with\\_acting/](http://www.boston.com/news/globe/living/articles/2007/05/26/newman_says_hes_done_with_acting/)). *The Boston Globe*. 26 May 2007. .
- [29] *Creating Minds: An Anatomy of Creativity Seen Through the Lives of Freud, Einstein, Picasso, Stravinsky, Eliot, Graham, and Gandhi* by Howard Gardner (1993)
- [30] Patenting Art and Entertainment by Gregory Aharonian and Richard Stim
- [31] Inventors Assistance League <http://www.inventions.org/>; License Your Invention by Richard Stim (2002); <http://inventorspot.com/>; United Inventors Association, <http://www.uiausa.org/>; The Inventor's Bible: How to Market and License Your Brilliant Ideas by Ronald Louis Docie (2004)
- [32] Diffusion of Innovations, 5th Edition by Everett Rogers (2003), also see [http://www.ciadvertising.org/studies/student/98\\_fall/theory/honor/paper1.html](http://www.ciadvertising.org/studies/student/98_fall/theory/honor/paper1.html)
- [33] Les lois de l'imitation Gabriel Tarde (1890)

## References

- Asimov, Isaac. Asimov's Chronology of Science and Discovery, Harper & Row, 1989. ISBN 0-06-015612-0
- De Bono, Edward, "Eureka! An Illustrated History of Inventions from the Wheel to the Computer", Thames & Hudson, 1974.
- Gowlett, John. Ascent to Civilization, McGraw-Hill, Inc., 1992. ISBN 0-07-544312-0
- Platt, Richard, "Eureka!: Great Inventions and How They Happened", 2003.
- Patenting Art and Entertainment by Gregory Aharonian and Richard Stim (2004)

## External links

- List of PCT (Patent Cooperation Treaty) Notable Inventions (<http://www.wipo.int/pct/en/inventions/inventions.html>) (on the WIPO web site)

# Timeline of historic inventions

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The **timeline of historic inventions** is a chronological list of particularly important or significant technological inventions.

*Note:* Dates for inventions are often controversial. Inventions are often invented by several inventors around the same time, or may be invented in an impractical form many years before another inventor improves the invention into a more practical form. Where there is ambiguity, the date of the first known working version of the invention is used here.

## Paleolithic era

Note that dates in the Paleolithic are especially uncertain and often change, usually to an earlier date.

- Music, Language, Culture
  - 2.6 million years ago (Ma): Olduwan – struck stone tools, in East Africa
  - 1.65 Ma: Acheulean – struck and reworked stone tools, in Kenya
  - 500 thousand years ago (ka): Shelter construction <sup>[1]</sup>
  - 500–250 ka: Controlled fire and sterilization of food and water (cooking) in East Africa <sup>[2]</sup>
  - 400 ka: Pigments in Zambia <sup>[3]</sup>
  - 400 ka: Spears in Germany <sup>[4]</sup>
  - 160–40 ka: Burial <sup>[5]</sup>
  - 140 ka: Bone tools in Africa (see Blombos Cave)
  - 60 ka: Bow <sup>[6]</sup>
  - 43 ka: Flute in Slovenia (disputed) <sup>[7]</sup>
  - 43 ka: Mining in Swaziland <sup>[8]</sup>
  - 40 ka: Boats used by settlers of New Guinea / Australia <sup>[9]</sup>
  - 36 ka: Cloth woven from flax fiber <sup>[10] [11]</sup>
  - 35 ka: Flute in Germany <sup>[12]</sup>
  - 31 ka: Domestication - earliest known domestic dog. <sup>[13]</sup>
  - 28–22 ka: Ceramics in Moravia (see Venus of Dolní Věstonice)
  - 28–17 ka: twisted Rope <sup>[14] [15]</sup>
  - 18 ka: Dot map (of stars), Lascaux caves in France
  - 16 ka: Pottery <sup>[16]</sup>
  - 15 ka: Domestic pig in the near east
-

## Antiquity

### 10th millennium BCE

- Agriculture (emmer wheat, einkorn wheat, barley and figs) in the Fertile Crescent (see Neolithic Revolution)
- Alcoholic beverages in the Fertile Crescent
- Adobe building material in the ancient Near East

### 9th millennium BCE

- 8700 BC: Metalworking (copper pendant) in Mesopotamia

### 8th millennium BCE

- Animal breeding in the ancient Near East
- Domestic sheep in Mesopotamia
- Domestic goat in Ganj Dareh
- Domestic cattle (see List of domesticated animals)
- 7500 BCE: Domestic cat in the near east

### 7th millennium BCE

- 7000 BCE: Dental drill in Mehrgarh, Indus Valley Civilization<sup>[17]</sup>
- 6400 BCE: Lead beads in Çatalhöyük
- 6200 BCE: Map in Çatalhöyük (see History of cartography)
- Domestic chicken in India and Southeast Asia

### 6th millennium BCE

- Irrigation in the Fertile Crescent
- Milking in Central Europe<sup>[18]</sup>
- Beer in Sumer, Mesopotamia<sup>[19]</sup>
- City in Mesopotamia
- Plough in Mesopotamia
- Bitter vetch cultivated in Turkey
- Banana cultivation in Papua New Guinea

### 5th millennium BCE

- Wheel and axle combination in Mesopotamia (potter's wheel)
  - Beer and bread in Egypt
  - Bow drill in Mehrgarh, Indus Valley Civilization<sup>[20]</sup>
  - Ice skate in Scandinavia<sup>[21]</sup>
  - Sailing in Mesopotamia<sup>[22]</sup>
  - Arsenical bronze metalwork: Iran<sup>[23]</sup>
-

## 4th millennium BCE

- 4000 BCE: Canal in Mesopotamia
- 4000 BCE: Stone paved street in Ur, Mesopotamia
- 3807–3806 BCE: Timber-engineered roadway in England
- 3630 BCE: Silk in China
- 3600 BCE: Free-standing Masonry Architecture at Ġgantija, Gozo, Malta
- 3500 BCE: Wheel: Wheeled carts among the Proto-Indo-Europeans (see Bronocice pot) and in Sumer
- 3500 BCE: Meteoric iron beads in Gerzah, Egypt
- 3300 BCE: Writing in Sumer
- 3100 BCE: Drainage in the Indus Valley Civilization (India/Pakistan)
- 3000 BCE: Reservoir in Girnar, Indus Valley Civilization<sup>[24]</sup>
- 3000 BCE: Tin used in copper alloys (bronzes) in the Near East and the Balkans
- 3000 BCE: Antimony artifact found at Tello, Chaldea (present day Iraq)
- 3000 BCE: Surveying in Egypt
- Comb in Persia (Iran)
- River boats in Egypt
- Silver mining in Asia Minor
- Gold artifacts in Varna Necropolis (Varna, Bulgaria)

## 3rd millennium BCE

- 2800 BCE: Soap in Mesopotamia
- 2800 BCE: Button in the Indus Valley Civilization (India/Pakistan)
- 2800 BCE: Bathroom in the Indus Valley Civilization<sup>[25]</sup>
- 2800 BCE: Toilet in Mohenjo-daro, Indus Valley Civilization<sup>[25]</sup>
- 2700–3000 BCE: Smelted iron in Asmar, Mesopotamia and Tall Chagar Bazaar, northern Syria
- 2700 BCE: Plumbing in the Indus Valley Civilization<sup>[25]</sup>
- 2700 BCE: Sanitary sewer in the Indus Valley Civilization<sup>[25]</sup>
- 2700 BCE: Sewage collection and disposal in the Indus Valley Civilization<sup>[25]</sup>
- 2630–2611 BCE: Step pyramid: Imhotep in Egypt
- 27th century BCE: Papyrus: Imhotep in Egypt
- 27th century BCE: Suture: Imhotep in Egypt
- 27th century BCE: Pharmaceutical cream: Imhotep in Egypt
- 2600 BCE: Chariot in Mesopotamia
- 2500 BCE: Arch in Mohenjo-daro, Indus Valley Civilization<sup>[26]</sup>
- 2500 BCE: Puppet in the Indus Valley Civilization<sup>[27]</sup>
- 2500–1900 BCE: Furnace in Balakot, Indus Valley Civilization<sup>[28]</sup>
- 2500–900 BCE: Oven in Balakot, Indus Valley Civilization<sup>[28]</sup>
- 2300–2500 BCE: Map using surveying in Babylonia
- 2400 BCE: Shipyard in Lothal, Indus Valley Civilization
- 2400 BCE: Dock in Lothal, Indus Valley Civilization<sup>[29]</sup>
- 2400 BCE: Ruler in Lothal, Indus Valley Civilization<sup>[30]</sup>
- 2000 BCE: Currency
- Dice in the Indus Valley Civilization<sup>[31]</sup>
- Dye in Mohenjo-daro, Indus Valley Civilization<sup>[32]</sup>
- Public bath in Mohenjo-daro, Indus Valley Civilization<sup>[33]</sup>
- Aqueduct in ancient Egypt and Indus Valley Civilization
- Candles in Egypt

- Dagger in Near East
- Sickle-sword in Sumer
- Alphabet in Phoenicia
- Ink in China
- Sledges in Scandinavia
- Ski in Scandinavia<sup>[19]</sup>
- Noodle in China

## 2nd millennium BCE

- 1900 BCE: Veterinary medicine in ancient Egypt and Vedic India<sup>[34]</sup>
- 17th century BCE: Bronze Age sword in Mesopotamia
- 1800–1200 BCE: Iron artifacts in Anatolia, Caucasus and India
- 1500–400 BCE: Kabaddi in India<sup>[35]</sup>
- 1500 BCE: Mercury found in Egyptian tombs
- 12th century BCE: Iron Age sword Proto-Celtic
- 11th century BCE: Coins in China
- 1000 BCE: Lens in Assyria<sup>[36]</sup>
- 1000 BCE: Central heating: Ondol in Korea<sup>[37]</sup>
- Perfume: Tapputi in Mesopotamia
- Glass in Egypt<sup>[38]</sup>
- Rubber in Mesoamerica
- Spoked-wheel: Indo-Iranians
- Water clock in Egypt
- Bells in China
- Fork in China<sup>[39]</sup>
- Umbrella in Mesopotamia
- Calibration in the Indus Valley Civilization<sup>[40]</sup>
- Metrology in the Indus Valley Civilization<sup>[40]</sup>
- Tin-glazing in Mesopotamia<sup>[41]</sup>

## 1st millennium BCE

- 1000 BCE: Dike in the Indus Valley Civilization<sup>[42]</sup>
- 750 BCE: Celestial spheres in ancient Greece<sup>[43]</sup>
- 8th century BCE: Button in Ancient Greece, Etruscan civilization<sup>[19]</sup>
- 700 BCE: Chain pump in Babylonia
- 7th century BCE: Latin alphabet in Ancient Rome
- 600 BCE: Chopsticks in China
- 592 BCE: Anchor in ancient Greece<sup>[44]</sup>
- 6th century BCE: Dental bridge in Etruria
- 6th century BCE: Kite: Lu Ban in China
- 6th century BCE: Plastic surgery: Sushruta in India
- 6th century BCE: Rhinoplasty: Sushruta
- 6th century BCE: Cataract surgery: Sushruta<sup>[45]</sup>
- 500 BCE: Iron plough in China
- 500–100 BCE: Big-toe stirrup in India<sup>[46]</sup> <sup>[47]</sup>
- 499–477 BCE: Horse collar in China<sup>[48]</sup>
- 475 BCE: Scythed Chariot: Ajatashatru in India

- 5th century BCE: Linguistics: Pāṇini in India<sup>[49]</sup>
- 5th century BCE: Traction trebuchet in China
- 5th century BCE: Catapult in ancient Greece<sup>[50]</sup>
- 5th century BCE: Wheelbarrow in Greece
- 5th century BCE: Cast iron in China
- 5th century BCE: Crossbow in China and Greece
- 350 BCE: Water wheel in India<sup>[51]</sup>
- 350 BCE: Watermill in India<sup>[51]</sup>
- 4th century BCE: Noria in India<sup>[51]</sup>
- c. 300 BCE: Wootz steel in India<sup>[52]</sup>
- 300 BCE: Crucible steel in India<sup>[53]</sup>
- 4th century BCE: Roman aqueduct in ancient Rome<sup>[54]</sup>
- 4th century BCE: Compass in China
- 4th century BCE: Star catalogues: Gan De and Shi Shen
- 4th century BCE: Encyclopedia: Speusippus in ancient Greece<sup>[19]</sup>
- 4th century BCE: Screw: Archytas
- 4th century BCE: India ink in India
- 4th century BCE: Coal mining for metalworking by the Greeks
- 300–100 BCE: Blast furnace in China
- 300–100 BCE: Cupola furnace in China
- 300–100 BCE: Pig iron in China
- 3rd century BCE: Diamond gemstone in India<sup>[55]</sup>
- 3rd century BC: Clockwork escapement mechanism: Philo of Byzantium of Ancient Greece<sup>[56]</sup>
- 285 BCE: Suspension bridge in China
- 250 BCE: Lever in ancient Greece
- 210 BCE: Chromium use in China
- 3rd century BCE: Compound pulley: Archimedes
- 3rd century BCE: Odometer: Archimedes?
- 3rd century BCE: Archimedes' screw : Archimedes
- 3rd century BCE: Cashmere wool in India<sup>[57]</sup>
- 3rd century BCE: Contour canal: Shi Lu in China
- 3rd century BCE: Lock gate in China
- 3rd century BCE: Stupa in India<sup>[58]</sup>
- 3rd century BCE: Pagoda in India<sup>[58]</sup>
- 202–1 BCE: Bellows in China
- 200 BCE: Horseshoe in ancient Rome
- 150s BCE: Clockwork (Antikythera mechanism)
- 150s BCE: Astrolabe: Hipparchus
- 100 BCE: Glassblowing in ancient Rome<sup>[59]</sup>
- 2nd century BCE: Parchment in Pergamon
- 500 BCE: Heavy plough in China
- 100 BCE: Trip hammer in China
- 52 BCE: Armillary sphere: Geng Shouchang in China
- 40 BCE: Rolling-element bearing in Roman ship
- 21 BCE: Collapsible umbrella: Wang Mang<sup>[60]</sup>
- Cautery in Ancient Rome<sup>[61]</sup>
- Speculum in Ancient Rome<sup>[61]</sup>

- Cross-bladed scissors in Ancient Rome<sup>[61]</sup> <sup>[62]</sup>
- Surgical needle in Ancient Rome<sup>[61]</sup>
- Catapult in ancient Near East
- South Pointing Chariot in China
- Differential gear in China and Greek island of Antikythera
- Flash lock in China
- Bookbinding in India
- Blowgun in India<sup>[63]</sup>
- Indigo dye in India<sup>[64]</sup>
- Iron pellet in India<sup>[63]</sup>
- Jute in Bengal<sup>[65]</sup>
- Toothbrush: Neem in India
- Scissors Mesopotamia or Egypt

## 1st millennium CE

### 1st–5th centuries

- 1–100 CE: Junk ship in China
- 1–100 CE: Junk rudder in China<sup>[66]</sup>
- 38 CE: Hydraulic-powered bellows: Du Shi
- 50 CE: Mouldboard plough in China and Gaul
- 77 CE: Encyclopedia (comprehensive work): Pliny the Elder<sup>[19]</sup>
- 78–139: Hydraulic-powered armillary sphere: Zhang Heng
- 2nd century: water sluice in water management Sri Lanka
- 2nd century: Lateen sail by Greco-Roman sailors<sup>[67]</sup> <sup>[68]</sup> <sup>[69]</sup> <sup>[70]</sup> <sup>[71]</sup> <sup>[72]</sup> <sup>[73]</sup> <sup>[74]</sup> <sup>[75]</sup> <sup>[76]</sup>
- 2nd century: Steam power: Hero of Alexandria in Roman Egypt
- 2nd century: Vending machine: Hero of Alexandria
- 2nd century: Force pump: Hero of Alexandria
- 2nd century: Carding in India<sup>[77]</sup>
- 105: Paper: Cai Lun in China<sup>[78]</sup>
- 132: Rudimentary Seismometer: Zhang Heng in China
- 180: Rotary fan: Ding Huan in China
- 180: Winnowing fan: Ding Huan in China
- 3rd century: Kongming lantern (Hot air balloon) in China
- 3rd century: Horseshoes in Germany
- 200–400: Stepwell in India<sup>[79]</sup>
- Combination lock in Roman Empire<sup>[80]</sup>
- 4th century: Corrosion-resistant iron: Iron pillar of Delhi in India<sup>[81]</sup>
- 4th century: Toothpaste in Roman Egypt
- 4th century: Crystallized Sugar in India
- 5th century: Horse collar in China
- 5th century: Cotton gin in India<sup>[82]</sup>
- Fore-and-aft rig in India<sup>[83]</sup>
- Kamal in India<sup>[84]</sup>
- Prayer wheel: Tibet<sup>[85]</sup>
- Three-masted merchant vessel in China<sup>[86]</sup>
- Woodblock printing in China

## 6th–8th centuries

- 6th century: Chaturanga, a precursor of chess: India<sup>[87]</sup>
- 6th century: Pachisi, a precursor of Ludo: India<sup>[88]</sup>
- 6th century: Incense clock in India<sup>[89]</sup> [90]
- 589: Toilet paper: Yan Zhitui in China
- 591: Gusli: East Slavs<sup>[91]</sup>
- 605: Fully-stone open-spandrel segmental arch bridge: Li Chun in China
- 618–700: Porcelain in China
- 618–907: Water-powered rotary fan in China
- 673: Greek fire flamethrower: Kallinikos of Heliopolis
- 700: Quill pen
- 700–900: Charitable trust in the Arab Empire<sup>[92]</sup> [93]
- 8th century: Inoculation: Madhav in India<sup>[94]</sup>
- 721–815: Distilled alcohol: Jābir ibn Hayyān<sup>[95]</sup>
- 721–815: Nitric, hydrochloric, sulfuric, tartaric and citric acid, aqua regia, and concentrated acetic acid: Jābir ibn Hayyān<sup>[96]</sup> [97] [98]
- 754: Pharmacy in Baghdad<sup>[99]</sup>
- 758–764: Tar pavement in Baghdad<sup>[100]</sup>
- 763–800: Psychiatric hospital: Bimaristan in Baghdad<sup>[101]</sup>
- Dry distillation: Arabic chemists
- Petrol: Arabic chemists<sup>[102]</sup>

## 9th–10th centuries

- 700–1000: Spinning wheel in India<sup>[103]</sup>
- 800–850: Mural instrument: Muhammad ibn Mūsā al-Khwārizmī<sup>[104]</sup>
- 800–850: Sine quadrant: Muhammad ibn Mūsā al-Khwārizmī<sup>[104]</sup>
- 800–850: Horary quadrant: Muhammad ibn Mūsā al-Khwārizmī<sup>[104]</sup>
- 800–857: Under-arm deodorant: Ziryab<sup>[105]</sup>
- 800–857: Beauty parlour: Ziryab<sup>[106]</sup>
- 800–857: Chemical depilatory: Ziryab<sup>[106]</sup>
- 800–873: Programmable machine: Banū Mūsā<sup>[107]</sup>
- 800–873: Gas mask: Banū Mūsā<sup>[108]</sup>
- 800–873: Clamshell grab: Banū Mūsā<sup>[108]</sup>
- 800–873: Mechanical musical instrument: Banū Mūsā<sup>[109]</sup>
- 800–873: Hurricane lamp: Banū Mūsā<sup>[108]</sup>
- 800–873: Self-feeding oil lamp: Banū Mūsā<sup>[108]</sup>
- 800–873: Self-trimming oil lamp: Ahmad ibn Mūsā ibn Shākir<sup>[108]</sup>
- 9th century: Muslin in Dhaka, Bengal<sup>[110]</sup> [111]
- 9th century: Stonepaste ceramics in Iraq<sup>[112]</sup>
- 9th century: Black powder in China
- 9th century: Water turbine in the Arab Empire<sup>[108]</sup>
- 9th century: Universal sundial in Baghdad<sup>[113]</sup>
- 9th century: Universal horary dial in Baghdad<sup>[114]</sup> [115]
- 9th century: Vertical-axle windmill in Afghanistan<sup>[116]</sup>
- 9th century: Naphtha in Azerbaijan<sup>[100]</sup>
- 9th century: Oil well in Azerbaijan<sup>[100]</sup>
- 9th century: College: Madrasah in the Muslim world<sup>[117]</sup>



- 800–1000: Wind powered gristmills in Afghanistan, Pakistan and Iran<sup>[118]</sup>
- 800–1000: Sugar refinery in Afghanistan, Pakistan and Iran<sup>[118]</sup>
- 800–1000: Metal block printing in Egypt<sup>[119]</sup>
- c. 800–1000: Switch: Arabic engineers<sup>[120]</sup>
- 801–1000: Municipal solid waste handling: Al-Kindi, Qusta ibn Luqa, Muhammad ibn Zakarīya Rāzi, Ibn Al-Jazzar, al-Masihi<sup>[121]</sup>
- 810–887: Metronome: Abbas Ibn Firnas<sup>[122]</sup>
- 810–887: Artificial weather simulation: Abbas Ibn Firnas<sup>[122]</sup>
- 827: Mechanical singing bird automaton: Al-Ma'mun<sup>[123]</sup>
- 836–1000: Erectile dysfunction treatment: Muhammad ibn Zakarīya Rāzi, Thabit bin Qurra (Thebit), Ibn Al-Jazzar<sup>[124]</sup>
- 853–929: Observation tube: Muhammad ibn Jābir al-Harrānī al-Battānī (Albatenius)<sup>[125]</sup>
- 859: University: Fatima al-Fihri<sup>[126] [127]</sup>
- 875: Hang glider: Abbas Ibn Firnas<sup>[122] [128]</sup>
- 875: Artificial wing: Abbas Ibn Firnas<sup>[122] [128]</sup>
- c. 865–900: Kerosene: Muhammad ibn Zakarīya Rāzi (Rhazes) in Iraq<sup>[100] [129]</sup>
- 10th century: Banknote in China
- 10th century: Fire lance in China
- 10th century: Gun in China
- 10th century: Milling factory in Baghdad<sup>[130]</sup>
- 10th century: Graph paper in the Arab Empire<sup>[131] [132] [133]</sup>
- 10th century: Horizontal-axle windmill in Afghanistan, Pakistan and Iran<sup>[116]</sup>
- 904: Fire Arrow in China
- 919: Double-piston flamethrower in China
- 984: Pound lock: Qiao Weiyo
- 953: Fountain pen: Al-Muizz Lideenillah of Egypt<sup>[134] [135]</sup>
- 989: Bread drink: East Slavs in Kievan Rus<sup>[136]</sup>
- 989: Multidomed church: East Slavs in Kievan Rus<sup>[137] [138]</sup>
- 994: Astronomical sextant: Abu-Mahmud al-Khujandi in Persia<sup>[139]</sup>
- 996: Geared mechanical astrolabe: Abū Rayhān al-Bīrūnī<sup>[140]</sup>
- Almuqantar quadrant: Arabic astronomers<sup>[141]</sup>
- Vertical sundial: Arabic astronomers<sup>[104]</sup>
- Polar sundial: Arabic astronomers<sup>[104]</sup>
- Shaving soap: Arabic chemists
- Reed level: Arabic engineers<sup>[142]</sup>
- Geared gristmill: Arabic engineers<sup>[143]</sup>
- Street lamp in the Arab Empire<sup>[144]</sup>
- Sherbet in the Arab Empire<sup>[145]</sup>
- Soft drink in the Arab Empire<sup>[145] [146]</sup>
- Syrup in the Arab Empire<sup>[145]</sup>
- Mercury escapement mechanism in the Middle East
- Public library in the Arab Empire<sup>[147]</sup>
- Library catalog in the Arab Empire<sup>[148]</sup>
- Snakes and ladders in India

## 2nd millennium

### 11th century

- c. 1000: Hypodermic needle: Ammar ibn Ali al-Mawsili<sup>[149]</sup> [150]
- c. 1000: Cataract extraction: Ammar ibn Ali al-Mawsili<sup>[149]</sup> [150]
- c. 1000: Suction: Ammar ibn Ali al-Mawsili<sup>[149]</sup> [150]
- 1000: Ligature: Abu al-Qasim al-Zahrawi (Abulcasis) in Al-Andalus<sup>[151]</sup>
- 1000: Adhesive plaster: Abu al-Qasim<sup>[152]</sup>
- 1000: Lithotomy scalpel: Abu al-Qasim<sup>[153]</sup>
- 1000: Surgical catgut: Abu al-Qasim
- 1000: Inhalational anaesthetic: Abu al-Qasim<sup>[100]</sup> [154]
- 1000: Anaesthetic sponge: Abu al-Qasim<sup>[100]</sup> [154]
- 1000: Oral anaesthesia: Abu al-Qasim<sup>[100]</sup> [154]
- 1000: Cotton dressing: Abu al-Qasim<sup>[155]</sup>
- c. 1000–1020: Heliocentric astrolabe: Al-Sijzi<sup>[156]</sup>
- c. 1000–1037: Essential oil: Avicenna<sup>[157]</sup>
- c. 1000–1048: Orthographical astrolabe: Abū Rayhān al-Bīrūnī in Persia
- c. 1000–1048: Planisphere: Abū Rayhān al-Bīrūnī<sup>[158]</sup>
- c. 1000–1048: Laboratory flask: Abū Rayhān al-Bīrūnī<sup>[159]</sup>
- c. 1000–1048: Pycnometer: Abū Rayhān al-Bīrūnī<sup>[159]</sup>
- c. 1000–1048: Conical measure: Abū Rayhān al-Bīrūnī<sup>[160]</sup>
- c. 1000–1048: Geared mechanical lunisolar calendar analog computer: Abū Rayhān al-Bīrūnī<sup>[161]</sup>
- 1020: Mechanical astrolabe: Ibn Samh in Al-Andalus<sup>[162]</sup>
- 1021: Magnifying glass: Ibn al-Haytham<sup>[163]</sup>
- 1021: Pinhole camera: Ibn al-Haytham<sup>[164]</sup>
- 1021: Camera obscura: Ibn al-Haytham<sup>[164]</sup>
- 1021: Novel: Murasaki Shikibu<sup>[165]</sup>
- 1021: Historical novel: Murasaki Shikibu<sup>[166]</sup>
- 1025: Calcium channel blocker: Avicenna<sup>[167]</sup>
- 1028–1087: Equatorium: Abū Ishāq Ibrāhīm al-Zarqālī (Arzachel) in Al-Andalus<sup>[168]</sup>
- 1028–1087: Universal astrolabe: Abū Ishāq Ibrāhīm al-Zarqālī
- 1031–1095: Raised-relief map: Shen Kuo<sup>[169]</sup> [170]
- 1038–1075: Flywheel: Ibn Bassal in Al-Andalus<sup>[171]</sup>
- 1041: Movable type printing press: Bi Sheng in China
- 1044: Hand grenade: Zhen Tian Lei in China
- 1087: Almanac: Abū Ishāq Ibrāhīm al-Zarqālī<sup>[172]</sup>
- 1088: Mechanical clock: Su Song
- 1088: Clock tower: Su Song
- 1088: Magnetic compass: Shen Kuo in China
- 1090: Belt drive: Qin Guan in China
- 1090: Chain drive in China
- 1092: Astronomical clock: Su Song
- 1094: Printed star chart: Su Song
- Calico in India<sup>[173]</sup>
- Coke fuel in China
- Epicyclic gearing: Ibn Khalaf al-Muradi in Al-Andalus<sup>[174]</sup>
- Segmental gearing: Ibn Khalaf al-Muradi in Al-Andalus<sup>[174]</sup>

- Geared mechanical clock: Ibn Khalaf al-Muradi in Al-Andalus<sup>[174]</sup>
- Weight-driven mechanical clock: Arabic engineers<sup>[174]</sup>
- Clear glass mirror in Al-Andalus<sup>[100]</sup>
- Koch (wooden icebreaker) by Pomors in Russia

## 12th century

- c. 1100: Framed bead abacus in China
- 1100–1150: Torquetum: Jabir ibn Aflah (Geber)<sup>[175]</sup>
- 1119: Watertight hull compartment: Zhu Yu in China
- 1126: Fire arrow: Li Gang in China
- 1126: Rocket: Li Gang in China
- 1128: Cannon in China<sup>[176]</sup>
- 1135–1200: Linear astrolabe: Sharaf al-Dīn al-Tūsī in Persia<sup>[177]</sup>
- 1187: Counterweight trebuchet: Mardi bin Ali al-Tarsusi<sup>[178]</sup> <sup>[179]</sup>
- 1187: Mangonel: Mardi bin Ali al-Tarsusi<sup>[180]</sup>
- 1190: Mariner's compass in Italy<sup>[181]</sup>
- Astrolabic quadrant in Egypt<sup>[182]</sup>
- Bridge mill in Al-Andalus<sup>[118]</sup>
- Hydropowered forge in Al-Andalus<sup>[118]</sup>
- Finery forge in Al-Andalus<sup>[118]</sup>
- Fireworks in China
- Pernach in the Kievan Rus'
- Shashka by Circassians in the Northern Caucasus
- Sunglasses in China

## 13th century

- c. 1200: Glass mirror in Europe<sup>[19]</sup> <sup>[183]</sup>
- 1206: Bolted joint lock<sup>[108]</sup>
- 1232: Rocket launcher in China
- 1235: Geared astrolabe with analog computer calendar: Abi Bakr of Isfahan<sup>[184]</sup>
- 1259: Research institute: Nasīr al-Dīn al-Tūsī<sup>[185]</sup>
- 1260: Hand cannon in Egypt<sup>[96]</sup> <sup>[186]</sup>
- 1260: Explosive gunpowder in Egypt<sup>[96]</sup> <sup>[186]</sup>
- 1260: Cartridge in Egypt<sup>[186]</sup>
- 1270: Pure saltpetre: Hasan al-Rammah of Syria<sup>[96]</sup> <sup>[186]</sup>
- 1274: Siege cannon: Abu Yaqub Yusuf<sup>[186]</sup>
- 1275: Torpedo: Hasan al-Rammah of Syria
- 1275: Restaurant menu in China
- 1277: Land mine: Lou Qianxia in China
- c. 1296: Astronomical compass: Yemeni sultan al-Ashraf<sup>[187]</sup>
- 1297–1298: Wooden movable type printing: Wang Zhen of China <sup>[188]</sup>
- Crankshaft-driven screw: Arabic engineers<sup>[130]</sup>
- Crankshaft-driven screw pump: Arabic engineers<sup>[130]</sup>
- Onion dome in Russia<sup>[189]</sup>
- Sandpaper in China
- Sokha in the Novgorod Republic, Russia<sup>[190]</sup>
- Solid-fuel rocket in China

- Condom in Italy
- Buttonhole in Germany<sup>[19]</sup>
- Snakes and ladders in India<sup>[191]</sup>

### 14th century

- 1304–1375: Compendium instrument: Ibn al-Shatir<sup>[104]</sup>
- 1350: Rope bridge in Peru
- 1355: Bombard: Jiao Yu and Liu Ji
- 1355: Matchlock: Jiao Yu and Liu Ji
- 1355: Multistage rocket: Jiao Yu and Liu Ji
- 1355: Naval mine: Jiao Yu and Liu Ji
- 1355: Round shot: Jiao Yu and Liu Ji
- 1355: Shell: Jiao Yu and Liu Ji
- 1355: Wheellock: Jiao Yu and Liu Ji
- 32-point compass rose in the Arab world<sup>[192]</sup>
- Katana in Japan
- Musket in China
- Spherical astrolabe in the Middle East
- Zvonitsa in Russia

### 15th century

- 1400–1429: Plate of conjunctions: Jamshīd al-Kāshī<sup>[193]</sup> [185]
- 1400–1429: Planetary analog computer: Jamshīd al-Kāshī<sup>[185]</sup> [194] [195]
- 1405–1433: Treasure ship: Zheng He
- c. 1430: Vodka: Isidore in Russia
- 1450s: Alphabetic movable type printing press: Johannes Gutenberg
- 1451: Concave lens for eyeglasses: Nicholas of Cusa
- 1490–1492: Terrestrial globe: Martin Behaim
- 1494: Double-entry bookkeeping system: Luca Pacioli
- 1498: Bristle toothbrush: Hongzhi Emperor
- Bardiche in Eastern Europe and Russia
- Mobile modular fortification in Russia
- Iron-chain suspension bridge in China
- Arquebus in Europe
- Rifle in Europe

### 16th century

- c. 1500: Ball bearing: Leonardo Da Vinci
- 1510s: Tented roof masonry in Russia
- 1540: Ether: Valerius Cordus
- 1551: Steam turbine: Taqi al-Din in Ottoman Egypt<sup>[196]</sup>
- 1559: Six-cylinder pump: Taqi al-Din<sup>[197]</sup>
- 1565: Pencil: Conrad Gesner<sup>[19]</sup> [198]
- 1579: Prefabricated home: Akbar the Great<sup>[199]</sup>
- 1579: Movable structure: Akbar the Great<sup>[199]</sup>
- c. 1580: Hookah: Hakim Abul Fateh Gilani in Mughal India<sup>[200]</sup> [201] [202]

- 1589: Stocking frame: William Lee
- 1589–1590: Seamless celestial globe: Ali Kashmiri ibn Luqman in Kashmir, Mughal India<sup>[203]</sup>
- c. 1590: Compound microscope: Zacharias Janssen, Hans Janssen, Hans Lippershey<sup>[204]</sup>
- 1592: Ironclad Warship: Yi Sun-sin
- 1593: Thermoscope: Galileo Galilei
- 1596: Water closet: John Harrington
- Chintz in India<sup>[173]</sup>
- Musket in Europe
- Pencil in England
- Vertical construction urban planning in Shibam<sup>[205]</sup>
- Shuriken in Japan

### 17th century

- 1608: Telescope: Hans Lippershey, Zacharias Janssen, Jacob Metius<sup>[206]</sup>
- 1610: Flintlock: Marin le Bourgeois
- 1620: Slide rule: William Oughtred
- 1623: Automatic calculator: Wilhelm Schickard
- 1624 or before: Temperature regulator: Cornelius Drebbel<sup>[207]</sup>
- 1631: Vernier scale: Pierre Vernier
- 1642: Adding machine: Blaise Pascal
- 1643: Barometer: Evangelista Torricelli
- 1645: Vacuum pump: Otto von Guericke
- 1657: Pendulum clock: Christiaan Huygens
- 1672: Steam car: Ferdinand Verbiest<sup>[208]</sup> <sup>[209]</sup>
- 1679: Pressure cooker: Denis Papin
- 1688: Balalaika in Russia
- 1690: Polhem wheel: Christopher Polhem
- 1698: Steam engine powered water pump: Thomas Savery
- 1700: Piano: Bartolomeo Cristofori
- c. 1700: Water-based central heating in Russia
- Palampore in India<sup>[173]</sup> <sup>[173]</sup>
- Russian Mountains (roller coaster) in Russia

### 18th century

- 1704: Decimal currency: Peter I of Russia
- 1709: Iron smelting using coke: Abraham Darby I
- 1711: Tuning fork: John Shore
- 1712: Steam piston engine: Thomas Newcomen
- 1714: Mercury thermometer: Daniel Gabriel Fahrenheit
- 1717: Mechanic slide rest: Andrey Nartov
- 1718: Yacht club: Peter I of Russia
- 1725: Rebar: Akinfiy Demidov
- 1731: Octant: John Hadley, Thomas Godfrey
- 1732: Cast iron dome: Akinfiy Demidov (see the Leaning Tower of Nevyansk)
- 1733: Flying shuttle: John Kay
- 1737: Marine chronometer (H1): John Harrison
- 1739: Ice palace: Anna of Russia and architect Pyotr Yeropkin

- 1740: Nail violin: Johann Wilde
  - 1742: Franklin stove: Benjamin Franklin
  - 1752: Lightning rod: Benjamin Franklin
  - 1753: Electrometer: Georg Wilhelm Richmann
  - 1754: Coaxial rotor / Model helicopter: Mikhail Lomonosov<sup>[210]</sup>
  - 1758: Binomial nomenclature system: Carl Linnaeus
  - 1762: Off-axis reflecting telescope: Mikhail Lomonosov
  - 1764: Spinning jenny: James Hargreaves/Thomas Highs
  - 1766: Two-cylinder engine: Ivan Polzunov
  - 1767: Carbonated water: Joseph Priestley
  - 1769: Water frame: Richard Arkwright/Thomas Highs
  - 1769: Steam road vehicle: Nicolas-Joseph Cugnot
  - 1775: Submarine Turtle: David Bushnell
  - 1776: Steamboat: Claude de Jouffroy
  - 1776: Watt steam engine: James Watt
  - 1777: Card teeth making machine: Oliver Evans
  - 1777: Circular saw: Samuel Miller
  - 1779: Candle searchlight: Ivan Kulibin
  - 1779: Spinning mule: Samuel Crompton
  - 1780: Copy machine for writing: James Watt
  - 1780s: Iron-cased rocket: Tipu Sultan in India<sup>[211]</sup>
  - 1783: Hot air balloon: Montgolfier brothers
  - 1783: Hydrogen balloon : Jacques Charles and Les Frères Robert
  - 1784: Bifocals: Benjamin Franklin
  - 1784: Argand lamp: Aimé Argand<sup>[19]</sup>
  - 1784: Shrapnel shell: Henry Shrapnel
  - 1785: Power loom: Edmund Cartwright
  - 1785: Automatic flour mill: Oliver Evans
  - 1786: Threshing machine: Andrew Meikle
  - 1791: Artificial teeth: Nicholas Dubois De Chemant
  - 1793: Screw drive elevator: Ivan Kulibin<sup>[212]</sup>
  - 1795: Appertization: Nicolas Appert
  - 1796: Peaked cap: Russian Army
  - 1798: Vaccination: Edward Jenner
  - 1798: Lithography: Alois Senefelder
  - Indian clubs in India<sup>[213]</sup>
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## 19th century

### 1800s

- 1800: Voltaic Pile: Alessandro Volta
- 1801: Jacquard loom: Joseph Marie Jacquard <sup>[214]</sup>
- 1802: Electric arc: Vasily Petrov
- 1802: Screw propeller steamboat *Phoenix*: John Stevens
- 1802: Gas stove: James Sharp
- 1803: Arc welding: Vasily Petrov
- 1803: Morphine (first isolation from opium): Friedrich W. A. Serturner <sup>[215]</sup>
- 1804: Steam locomotive: (*Puffing Devil*) – Richard Trevithick
- 1805: Submarine Nautilus: Robert Fulton
- 1807: Steamboat Clermont: Robert Fulton
- 1808: Bandsaw: William Newberry
- 1809: Arc lamp: Humphry Davy

### 1810s

- 1811: Sailor cap: Russian Navy
- 1812: Electric mine: Pavel Schilling
- 1814: Beehive frame: Petro Prokopovych
- 1814: Steam locomotive (*Blücher*) – George Stephenson
- 1816: Miner's safety lamp: Humphry Davy
- 1816: Stirling engine: Robert Stirling
- 1816: Stethoscope: Rene Theophile Hyacinthe Laennec
- 1817: Draisine or velocipede (two-wheeled): Karl Drais
- 1817: Kaleidoscope: David Brewster
- 1818: Bicycle: Karl Drais <sup>[19]</sup>

### 1820s

- 1820: Monorail: Ivan Elmanov
  - 1821: Electric motor: Michael Faraday
  - 1822: Photography: Joseph Nicéphore Niépce
  - 1823: Electromagnet: William Sturgeon
  - 1823: Lighter: Johann Wolfgang Döbereiner
  - 1824: Portland cement: William Aspdin
  - 1826: Internal combustion engine: Samuel Morey
  - 1827: Friction match: John Walker
  - 1827: Fountain-pen: Petrache Poenaru
  - 1829: Steam locomotive: (*Rocket*) – Robert Stephenson <sup>[19]</sup>
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**1830s**

- 1830: Thermostat: Andrew Ure<sup>[19]</sup>
- 1830: Stenotype on punched paper strip: Karl Drais
- 1831: Multiple coil magnet: Joseph Henry
- 1831: Magnetic acoustic telegraph: Joseph Henry (patented 1837)
- 1831: Reaper: Cyrus McCormick
- 1831: Electrical generator: Michael Faraday, Ányos Jedlik
- 1832: Electric Motor: William Sturgeon
- 1832: Electromagnetic telegraph: Pavel Schilling
- 1832: Unit record equipment: Semen Korsakov
- 1834: The Hansom cab is patented
- 1834: Braille system: Louis Braille
- 1834: Refrigerator: Jacob Perkins
- 1834: Combine harvester: Hiram Moore
- 1835: Centrifugal fan: Alexander Sablukov
- 1835: Revolver: Samuel Colt
- 1835: Electromechanical relay: Joseph Henry
- 1835: Incandescent light bulb: James Bowman Lindsay
- 1836: Sewing machine: Josef Madersperger
- 1837: Induction coil: Nicholas Callan
- 1837: US electric printing press patented by Thomas Davenport (February 25)
- 1837: Steel plow: John Deere
- 1837: Standard diving dress: Augustus Siebe<sup>[216]</sup>
- 1837: Camera Zoom Lens: Jozef Maximilián Petzval
- 1837: Magnetic telegraph: Samuel Morse
- 1838: closed diving suit with a helmet: Augustus Siebe<sup>[216]</sup>
- 1838: Electrotyping: Boris Jacobi<sup>[217]</sup>
- 1838: Electric boat: Boris Jacobi
- 1838: Galvanoplastic sculpture: Boris Jacobi and Heinrich Lenz<sup>[217]</sup>
- 1839: Vulcanization of rubber: Charles Goodyear

**1840s**

- 1840: Artificial fertilizer: Justus von Liebig
  - 1841: Saxophone: Adolphe Sax
  - 1842: Superphosphate fertilizer: John Bennett Lawes
  - 1842: Steam hammer: James Nasmyth
  - 1842: Anaesthesia: Crawford Long
  - 1843: Typewriter: Charles Thurber
  - 1843: Fax machine: Alexander Bain
  - 1843: Ice cream maker: Nancy Johnson
  - 1843: Steam powered Pile driver: James Nasmyth
  - 1844: The safety match: Gustaf Erik Pasch
  - 1844: Pulpwood for papermaking: Charles Fenerty (Nova Scotia, Canada), and F. G. Keller (Germany)
  - 1845: Rubber band: Stephen Perry
  - 1845: Pneumatic tyre: Robert Thomson (inventor)
  - 1846: Sewing machine: Elias Howe
  - 1846: Rotary printing press: Richard M. Hoe
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- 1848: Modern oil well: Vasily Semyonov<sup>[218]</sup>
- 1849: Safety pin: Walter Hunt
- 1849: Francis turbine: James B. Francis

### 1850s

- 1850: Modern bascule bridge: Stanisław Kierbedź
- 1852: Airship: Henri Giffard
- 1852: Passenger elevator: Elisha Otis
- 1852: Gyroscope: Léon Foucault
- 1855: Bunsen burner: Robert Wilhelm Bunsen
- 1855: Bessemer process: Henry Bessemer
- 1856: Celluloid: Alexander Parkes
- 1856: Condensed milk: Gail Borden
- 1857: Heating radiator: Franz San Galli
- 1858: Undersea telegraph cable: Charles Wheatstone
- 1858: Mason jar: John L. Mason
- 1859: Aluminothermy: Nikolay Beketov
- 1859: Oil drill: Edwin L. Drake
- 1859: Lead acid battery: Gaston Plante
- 1859: Ironclad (Battleship) La Gloire: Dupuy de Lôme
- Badminton in India<sup>[219]</sup> <sup>[220]</sup>

### 1860s

- 1860: Light Bulb, Sir Joseph Swan
  - 1860: Linoleum: Frederick Walton
  - 1860: Repeating rifle: Oliver F. Winchester, Christopher Spencer
  - 1860: Self-propelled torpedo: Giovanni Luppis
  - 1860: Vacuum cleaner: Daniel Hess
  - 1861: Siemens regenerative furnace: Carl Wilhelm Siemens
  - 1862: Revolving machine gun: Richard J. Gatling
  - 1862: Mechanical submarine: Narcís Monturiol i Estarriol
  - 1862: Pasteurization: Louis Pasteur, Claude Bernard
  - 1863: Player piano: Henri Fourneaux
  - 1863: Underground railway (metro, subway): Sir John Fowler
  - 1864: Metal-hull icebreaker: Mikhail Britnev
  - 1865: Barbed wire: Louis Jannin
  - 1866: Dynamite: Alfred Nobel
  - 1867: Paper clip: Samuel B. Fay
  - 1867–1969: Steam motorcycle: Michaux-Perreaux and Roper steam velocipedes
  - 1868: Typewriter: Christopher Sholes, Carlos Glidden and Samuel W. Soule, with assistance from James Densmore
  - 1869: Air brake (rail): George Westinghouse
  - 1868: Oleomargarine: Mege Mouries
  - 1869: Periodic table: Dmitri Mendeleev
  - 1869: Manually-powered vacuum cleaner: Ives W. McGaffey
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**1870s**

- 1870: Chewing gum: Thomas Adams<sup>[19]</sup>
- 1870: Magic lantern projector: Henry R. Heyl
- 1870: Stock ticker: Thomas Alva Edison
- 1871: Cable car (railway) (grip controlled): Andrew S. Hallidie
- 1873: Jeans: Levi Strauss<sup>[19]</sup>
- 1873: Odhner Arithmometer: Willgodt Theophil Odhner
- 1873: Railway knuckle coupler: Eli H. Janney
- 1873: Modern direct current electric motor: Zénobe Gramme
- 1874: Barbed wire: Joseph Glidden<sup>[19]</sup>
- 1874: Heroin: First synthesized by C. R. Alder Wright<sup>[221]</sup>
- 1874: Electric street car: Stephen Duple Field
- 1874: DDT: Othmar Zeidler<sup>[19]</sup>
- 1875: Dynamo: William Arnold Anthony
- 1875: Magazine (firearm): Benjamin B. Hotchkiss
- 1875: Railway electrification system: Fyodor Pirotsky
- 1876: Carpet sweeper: Melville Bissell
- 1876: Gasoline carburettor: Daimler
- 1876: Loudspeaker: Alexander Graham Bell
- 1876: Telephone: Alexander Graham Bell
- 1876: Yablochkov candle: Pavel Yablochkov
- 1877: Stapler: Henry R. Heyl
- 1877: Induction motor: Nikola Tesla
- 1877: Phonograph: Thomas Alva Edison
- 1877: Microphone: Emile Berliner
- 1877: Torpedo boat tender: Stepan Makarov
- 1877: Tracked wagon: Fyodor Blinov
- 1878: Cathode ray tube: William Crookes
- 1878: Cylindric oil depot: Vladimir Shukhov
- 1878: Rebreather: Henry Fleuss<sup>[222]</sup>
- 1879: Pelton turbine: Lester Pelton
- 1879: Long-lasting, practical incandescent light bulb: Thomas Alva Edison
- 1879: Cash register: James Ritty
- 1879: Metal-hull oil tanker: Ludvig Nobel

**1880s**

- 1880: Electric tram: Fyodor Pirotsky
  - 1880: Photophone: Alexander Graham Bell
  - 1880: Roll film: George Eastman
  - 1880: Safety razor: Kampfe Brothers
  - 1880: Seismograph: John Milne
  - 1881: Carbon arc welding: Auguste de Méritens
  - 1881: Metal detector: Alexander Graham Bell
  - 1882: Electric fan: Schuyler Skaats Wheeler
  - 1882: Blowtorch: Carl Rickard Nyberg
  - 1883: Photovoltaic cell: Charles Fritts
  - 1883: Two-phase (alternating current) induction motor: Nikola Tesla
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- 1884: Linotype machine: Ottmar Mergenthaler
- 1884: Recording data on a machine readable medium, the Punched card: Herman Hollerith
- 1884: Trolley car, (electric): Frank Sprague, Charles Van Depoele
- 1884: The Maxim Gun invented by Sir Hiram Maxim
- 1885: Roller Coaster: LaMarcus Adna Thompson
- 1885: Automobile patent granted (internal combustion engine powered): Karl Benz, first automobile put into production
- 1885: Machine gun: Hiram Stevens Maxim<sup>[223]</sup>
- 1885: Internal combustion motorcycle: Gottlieb Daimler and Wilhelm Maybach<sup>[224]</sup>
- 1885: Alternating current transformer: William Stanley
- 1885: Safety bicycle: John Kemp Starley
- 1886: Dishwasher: Josephine Cochrane
- 1886: Improved phonograph cylinder: Tainter & Bell
- 1887: Amphetamine: Lazăr Edeleanu<sup>[225]</sup>
- 1887: Monotype machine: Tolbert Lanston
- 1887: Contact lens: Adolf Gaston Eugen Fick, Eugène Kalt and August Muller
- 1887: Gramophone record: Emile Berliner
- 1887: Ceiling fan: Philip Diehl
- 1888: Caterpillar tractor: Fyodor Blinov
- 1888: Polyphase AC Electric power system: Nikola Tesla (30 related patents.)
- 1888: Kodak hand camera: George Eastman<sup>[226]</sup>
- 1888: Ballpoint pen: John Loud
- 1888: Cinematograph: Augustin Le Prince
- 1888: Photoelectric cell: Aleksandr Stoletov
- 1888: Manual metal arc welding: Nikolay Slavyanov
- 1888: Wind Energy : Charles F. Brush
- 1889: Northrop Loom: Draper Corporation, James Henry Northrop
- Takadiastase: Jokichi Takamine

### 1890s

- 1890: Centrifugal Pump: Byron Jackson This was a turbine pump which is now the standard pump design wherever water needs to be moved.
- 1890: Tungsten filament: Alexander Lodygin
- 1890: Zipper: Whitcomb L. Judson
- 1891: Escalator: Jesse W. Reno<sup>[19]</sup>
- 1891: Thermal cracking process: Vladimir Shukhov
- 1891: Carborundum: Edward G. Acheson
- 1891: Modern adjustable spanner: Johan Petter Johansson
- 1891: Tesla coil: Nikola Tesla
- 1892: Color photography: Frederic E. Ives
- 1892: Automatic telephone exchange (electromechanical): Almon Strowger – First in commercial service.
- 1893: Carburetor: Donát Bánki and János Csonka
- 1893: Tuned wireless communication: Nikola Tesla (The True Wireless)
- 1893: Radio: Nikola Tesla<sup>[227]</sup>
- 1894: Radio transmission: Jagdish Chandra Bose in Bengal<sup>[228]</sup>
- 1894: Milking machine: Gustaf de Laval
- 1894: Methamphetamine: Nagayoshi Nagai<sup>[229]</sup>

- 1894: Nephoscope: Mikhail Pomortsev
- 1895: X-ray : Wilhelm Conrad Röntgen
- 1895: Diesel engine: Rudolf Diesel
- 1895: Lightning detector / Radio receiver: Alexander Popov
- 1895: Radiotelegraph: Guglielmo Marconi
- 1896: Vitascope: Thomas Armat
- 1896: Hyperboloid structure: Vladimir Shukhov
- 1896: Tensile structure: Vladimir Shukhov
- 1896: Thin-shell structure: Vladimir Shukhov
- 1896: Gridshell: Vladimir Shukhov
- 1897: Modern escalator: Jesse W. Reno
- 1898: Polar icebreaker: Stepan Makarov
- 1898: Tapered roller bearing: Henry Timken
- 1898: Remote control: Nikola Tesla
- 1898: Ignition coil: Nikola Tesla
- 1899: Iron-mercury coherer: Jagdish Chandra Bose in Bengal
- 1899: Automobile self starter: Clyde J. Coleman
- 1899: Magnetic tape recorder: Valdemar Poulsen
- 1899: Gas turbine: Charles Curtis

## 20th century

### 1900s

- 1900: Epinephrine (adrenaline): Jokichi Takamine & Keizo Uenaka
  - 1900: Rigid dirigible airship: Ferdinand Graf von Zeppelin
  - 1900: Self-heating can
  - 1901: Chromatography: Mikhail Tsvet
  - 1901: Mercury vapor lamp: Peter Cooper Hewitt
  - 1901: Disposable razor blade: King C. Gillette
  - 1901: Motorized vacuum cleaner: Hubert Cecil Booth
  - 1901: Gauge blocks: Carl Edvard Johansson
  - 1902: Air Conditioner: Willis Carrier <sup>[19]</sup>
  - 1902: Fire fighting foam: Aleksandr Loran
  - 1902: Ostwald process: Wilhelm Ostwald
  - 1902: Neon lamp: Georges Claude
  - 1902: Radio telephone: Valdemar Poulsen, Reginald Fessenden
  - 1902: Rayon cellulose ester: Arthur D. Little
  - 1903: Diesel-electric transmission / Motor ship: Konstantin Boklevsky
  - 1903: Electrocardiograph (EKG): Willem Einthoven
  - 1903: Powered, controlled airplane: Wilbur Wright and Orville Wright
  - 1904: Foam extinguisher: Aleksandr Loran
  - 1904: Modern mortar: Leonid Gobyato
  - 1904: Thermionic valve: John Ambrose Fleming
  - 1904: Tractor: Benjamin Holt
  - 1905: Insubmersibility: Alexey Krylov and Stepan Makarov
  - 1905: Auscultatory blood pressure measurement: Nikolai Korotkov
  - 1905: Electric seismometer: Boris Galitzine
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- 1905: Radio tube diode: John Ambrose Fleming
- 1906: Sonar (first device): Lewis Nixon
- 1906: Triode amplifier: Lee DeForest
- 1907: Aerosan: Sergey Nezhdanovsky
- 1907: Helicopter: Paul Cornu
- 1907: Monosodium glutamate: Kikunae Ikeda<sup>[230]</sup>
- 1907: Radio tube triode: Lee DeForest
- 1907: Washing machine, (electric): Alva Fisher (Hurley Corporation)
- 1908: Cellophane: Jacques E. Brandenberger
- 1908: Geiger counter: Hans Geiger and Ernest Rutherford
- 1908: Gyrocompass: Hermann Anschütz-Kaempfe
- 1908: Haber process: Fritz Haber
- 1908: Umami: Kikunae Ikeda<sup>[231]</sup>
- 1909: Bakelite: Leo Baekeland
- 1909: Gun suppressor: Hiram Percy Maxim
- Microwave optics: Jagdish Chandra Bose in Bengal
- Crescograph: Jagdish Chandra Bose in Bengal<sup>[232]</sup>

### 1910s

- 1910: Aberic acid: Umetaro Suzuki
  - 1910: Classical conditioning: Ivan Pavlov
  - 1910: Thiamine (Vitamin B<sub>1</sub>): Umetaro Suzuki<sup>[233]</sup>
  - 1910: Vitamin (B vitamin): Umetaro Suzuki
  - 1910: Dental Braces: Joseph Clyde
  - 1910: Neon lighting: Georges Claude
  - 1911: Gyrocompass: Elmer A. Sperry
  - 1911: Automobile self starter (perfected): Charles F. Kettering
  - 1911: CRT television: Boris Rosing
  - 1911: Hydroplane: Glenn Curtiss
  - 1911: Knapsack parachute: Gleb Kotelnikov
  - 1912: Drogue parachute: Gleb Kotelnikov
  - 1913: Aerobatics: Pyotr Nesterov and Adolphe Pégoud
  - 1913: Airliner: Igor Sikorsky
  - 1913: Assault rifle: Vladimir Fyodorov
  - 1913: Bra: Mary Phelps Jacob
  - 1913: Crossword: Arthur Wynne
  - 1913: Half-track: Adolphe Kégresse
  - 1913: Radio receiver: Ernst Alexanderson, Reginald Fessenden
  - 1913: Stainless steel: Harry Brearley
  - 1913: X-Ray (coolidge tube): William D. Coolidge<sup>[234]</sup>
  - 1914: Aerial ramming: Pyotr Nesterov
  - 1914: Radio transmitter triode mod.: Ernst Alexanderson
  - 1914: Liquid fuel rocket: Robert Goddard
  - 1914: Strategic bomber: Igor Sikorsky
  - 1914: Tank, military: Sir William Ashbee Tritton and Major Walter Gordon Wilson<sup>[235]</sup>
  - 1915: Activated charcoal gas mask: James Bert Garner and Nikolay Zelinsky
  - 1915: Pyrex: Corning Inc.
-

- 1916: Browning Gun: John Browning
- 1916: Cultured pearl: Mikimoto Kōkichi
- 1916: Thompson submachine gun: John T. Thompson
- 1917: Sonar echolocation: Paul Langevin
- 1917: Cruise missile: Charles Kettering
- 1918: Air ionizer: Alexander Chizhevsky
- 1918: Interrupter gear: Anton Fokker
- 1918: Radio crystal oscillator: A.M. Nicolson
- 1919: Flip-flop circuit: William Eccles and F. W. Jordan
- 1919: Theremin: Léon Theremin

## 1920s

- 1920: Saha ionization equation: Meghnad Saha<sup>[236]</sup>
- 1921: Polygraph: John A. Larson
- 1922: Crystadine: Oleg Losev
- 1922: Radar: Robert Watson-Watt, A. H. Taylor, L. C. Young, Gregory Breit, Merle Antony Tuve
- 1922: The absorption refrigerator: Baltzar von Platen
- 1923: Sound film: Lee DeForest
- 1923: Television Electronic: Philo Farnsworth
- 1923: Wind tunnel: Michael Max Munk
- 1923: Autogyro: Juan de la Cierva
- 1923: Xenon flash lamp: Harold Edgerton
- 1924: Optophonic Piano: Vladimir Baranov-Rossine
- 1924: Automatic power loom: Sakichi Toyoda<sup>[237]</sup>
- 1925: Ultra-centrifuge: Theodor Svedberg – used to determine molecular weights
- 1925: Television Nipkow System: C. Francis Jenkins
- 1926: Interlace: Léon Theremin
- 1926: Television Mechanical Scanner: John Logie Baird
- 1926: Aerosol spray: Rotheim
- 1926: Yagi antenna: Hidetsugu Yagi & Shintaro Uda
- 1926: Directional antenna: Hidetsugu Yagi & Shintaro Uda
- 1926: High-gain antenna: Hidetsugu Yagi & Shintaro Uda
- 1927: Light-emitting diode: Oleg Losev
- 1927: Mechanical cotton picker: John Rust
- 1928: Rabbage: Georgii Karpechenko
- 1928: Sliced bread: Otto Frederick Rohwedder
- 1928: Electric dry shaver: Jacob Schick
- 1928: Antibiotics: Alexander Fleming (initial discovery of penicillin)
- 1928: Preselector gearbox: Walter Gordon Wilson
- 1928: Raman effect: Sir Chandrasekhara Venkata Raman<sup>[238]</sup>
- 1928: Magnetic interference balance: Shanti Swarup Bhatnagar & K. N. Mathur<sup>[239]</sup>
- 1928: 3D television John Logie Baird<sup>[240]</sup>
- 1929: Cadaveric blood transfusion: Sergei Yudin
- 1929: Electroencephelograph (EEG): Hans Berger
- 1929: Kinescope (CRT): Vladimir Zworykin
- 1929: Teletank / Military robot: Red Army
- Band aid: Earle Dickson

- Man-made Insulin: Paul Langerhans
- Mechanical potato peeler: Herman Lay
- Phototelegraphic transmission: Yasujiro Niwa
- Mechanical television: Yasujiro Niwa

### 1930s

- 1930: Neoprene: Wallace Carothers
  - 1930: Paratrooping: Russian Airborne Troops
  - 1930: Radiosonde: Pavel Molchanov
  - 1931: Magnetic-resistant steel: Kotaro Honda
  - 1931: Magnetic steel: Kotaro Honda
  - 1931: Alnico: Tokuhichi Mishima
  - 1931: MKM steel: Tokuhichi Mishima <sup>[241]</sup> <sup>[242]</sup>
  - 1931: Hypergolic propellant: Valentyn Glushko
  - 1931: Iconoscope: Vladimir Zworykin
  - 1931: Pressure suit: Yevgeny Chertovsky<sup>[243]</sup>
  - 1931: Rhythmicon / Drum machine: Léon Theremin
  - 1932: Radio telescope: Karl Jansky
  - 1932: Terpsitone: Léon Theremin
  - 1932: Underwater welding: Konstantin Khrenov
  - 1934: Cherenkov detector: Cherenkov radiation<sup>[244]</sup>
  - 1934: Hammond Organ: Laurens Hammond
  - 1935: Microwave RADAR: Robert Watson-Watt
  - 1935: Nylon: Wallace Carothers
  - 1935: Spectrophotometer: Arthur C. Hardy
  - 1937: Turboprop engine: György Jendrassik
  - 1937: Jet engine: Frank Whittle and Hans von Ohain
  - 1937: O-ring: Niels Christensen
  - 1937: Nylon: Wallace H. Carothers<sup>[19]</sup>
  - 1937: Portable electrocardiograph: Taro Takemi
  - 1937: Atanasoff–Berry Computer, the first automatic electronic digital computer: John Vincent Atanasoff
  - 1937: Polyphonic synthesizer: Harald Bode
  - 1937: Welded sculpture: Vera Mukhina
  - 1938: Ballpoint pen: Laszlo Biro
  - 1938: Deep column station: Alexey Dushkin
  - 1938: Xerography: Chester Carlson
  - 1938: Fiberglass: Russell Games Slayter John H. Thomas
  - 1938: LSD: Albert Hofmann
  - 1939: Modern helicopter (Focke-Wulf Fw 61): Igor Sikorsky
  - 1939: Kirlian photography: Semyon Kirlian
  - 1939: Automated teller machine: Luther George Simjian
  - Nuclear medicine: Frédéric Joliot-Curie, Irène Joliot-Curie, Taro Takemi
  - Spring-loaded camming device: Vitaly Abalakov<sup>[245]</sup>
  - Electric propulsion: Valentin Glushko
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**1940s**

- 1940: p-n junction: Russell Ohl<sup>[246]</sup>
- 1940: Fluorescent Light fixture manufacturing : Lightolier, Artcraft, Globe : [247]
- 1941: Computer: Konrad Zuse
- 1941: Maksutov telescope: Dmitry Maksutov
- 1941: Degaussing: Charles F. Goodeve and Anatoly Alexandrov
- 1941: Velcro: George de Mestral
- 1942: Bazooka Rocket Gun: Leslie A. Skinner C. N. Hickman
- 1942: Nuclear reactor: Enrico Fermi<sup>[19]</sup>
- 1942: Undersea oil pipeline: Hartley, Anglo-Iranian, Siemens in Operation Pluto
- 1942: Winged tank: Oleg Antonov
- 1943: Aqua-Lung: Jacques-Yves Cousteau and Emile Gagnan
- 1944: EPR spectroscopy: Yevgeny Zavoisky<sup>[248]</sup>
- 1944: Electron spectrometer: Deutsch Elliot Evans
- 1945: Passive resonant cavity bug: Léon Theremin
- 1945: Slinky: Richard James and Betty James
- 1945: Microwave oven: Percy L. Spencer<sup>[19]</sup>
- 1945: Nuclear weapons (note: chain reaction theory was made in 1933):Manhattan Project
- 1946: Microwave oven: Percy Spencer
- 1946: Mobile Telephone Service: AT&T and Southwestern Bell
- 1946: Bikini: Louis Réard<sup>[19]</sup>
- 1947: AK-47: Mikhail Kalashnikov
- 1947: Pocket calculator (four-function, mechanical): Curt Herzstark<sup>[249]</sup> [250]
- 1947: Transistor: William Shockley, Walter Brattain, John Bardeen
- 1947: Polaroid camera: Edwin Land
- 1948: Long Playing Record: Peter Carl Goldmark
- 1948: Holography: Dennis Gabor<sup>[19]</sup>
- 1949: Atomic clocks
- 1949: Radiocarbon dating: Willard Libby
- 1949: Kei car in Japan
- Electric rice cooker: Mitsubishi Electric

**1950s**

- 1950: Credit card: Frank X. McNamara
- 1950: Steadicam tracking shot: Akira Kurosawa
- 1951: Combined oral contraceptive pill: Djerassi, Miramontes, and Rosenkranz<sup>[251]</sup>
- 1951: Explosively pumped flux compression generator: Andrey Sakharov
- 1951: Liquid Paper: Bette Nesmith Graham
- 1951: Nuclear power reactor: Walter Zinn
- 1952: Carbon nanotubes: L. V. Radushkevich and V. M. Lukyanovich<sup>[252]</sup> [253]
- 1952: Ilizarov apparatus: Gavril Ilizarov
- 1952: Optical fiber: Narinder Singh Kapany<sup>[254]</sup> [255]
- 1952: Fusion bomb: Edward Teller and Stanislaw Ulam
- 1952: Hovercraft: Christopher Cockerell
- 1953: MASER: Charles Townes
- 1953: Medical ultrasonography
- 1954: Nuclear power plant: Igor Kurchatov



- 1954: Radar gun: Bryce K. Brown
- 1954: Silicon transistor: Bell Laboratories and Texas Instruments, independently
- 1954: Synthetic diamond: Tracy Hall
- 1954: Geodesic dome: Buckminster Fuller
- 1955: Fast-neutron reactor: Soviet Union
- 1955: Hard Drive: Reynold Johnson with IBM
- 1955: Bounce lighting: Subrata Mitra<sup>[256]</sup> <sup>[257]</sup>
- 1955: Submarine-launched ballistic missile: Victor Makeev
- 1955: Tokamak: Lev Artsimovich
- 1956: Digital clock
- 1956: Fortran: John W. Backus
- 1956: Videotape recorder: Ampex
- 1957: Electric compact calculator: Casio
- 1957: Jet Boat: William Hamilton
- 1957: Digital synthesizer: Max Mathews
- 1957: Intercontinental ballistic missile / Orbital space rocket: Sergey Korolev
- 1957: Satellite: Soviet space program (Sergey Korolev, Mstislav Keldysh, Mikhail Tikhonravov)
- 1957: Spaceport: Vladimir Barmin
- 1957: Space capsule: Soviet space program
- 1957: Synchrotron: Vladimir Veksler
- 1958: Integrated circuit: Jack Kilby of Texas Instruments, Robert Noyce at Fairchild Semiconductor
- 1958: Neutron Bomb: Samuel T. Cohen
- 1958: Communications satellite: Kenneth Masterman-Smith
- 1958: Implantable pacemaker: Rune Elmqvist
- 1958: Instant noodles: Momofuku Ando
- 1958: Ternary computer: Nikolay Brusentsov
- 1959: Dedicated high-speed rail lines (Shinkansen): Kawasaki Heavy Industries in Japan
- 1959: Nuclear icebreaker: Soviet Union
- 1959: Space probe: Soviet space program
- 1959: Spandex (aka Lycra or elastane): Joseph Shivers

### 1960s

- 1960: Laser: Theodore Harold Maiman
- 1960: Reentry capsule: Soviet space program
- 1961: Digital Photography: Eugene F. Lally
- 1961: Anti-ballistic missile: Pyotr Grushin
- 1961: Ekranoplan: Rostislav Alexeyev
- 1961: Optical disc: David Paul Gregg
- 1961: Cochlear implant: William House
- 1961: Human spaceflight: performed by Yuri Gagarin for Soviet space program (Sergey Korolyov, Kerim Kerimov and others)<sup>[258]</sup>
- 1961: Space food: Soviet space program
- 1961: Space suit: Soviet space program
- 1961: Platform screen doors: Saint Petersburg Metro
- 1961: Thin-film transistor: P. K. Weimer<sup>[259]</sup>
- 1962: 3D holography: Yuri Denisyuk
- 1962: Sea Solar Power<sup>[260]</sup> J. Hilbert Anderson<sup>[261]</sup>

- 1962: Light-emitting diode (LED): Nick Holonyak
- 1962: Trijet: Hawker Siddeley Aviation (Hawker Siddeley Trident) HS.121 or DH.121 Trident
- 1962: Space observatory: Ball Brothers Aerospace Corporation<sup>[262]</sup>
- 1963: Computer mouse: Douglas Engelbart
- 1964: Plasma propulsion engine: Soviet space program
- 1964: Solid-state electronic calculator: Friden, Inc.<sup>[263]</sup>
- 1965: Air-augmented rocket: Boris Shavyrin
- 1965: Extra-vehicular activity: performed by Alexey Leonov for the Soviet space program
- 1965: Molniya orbit satellite: Soviet space program
- 1966: Lander spacecraft: Soviet space program (Georgy Babakin)
- 1966: Orbital module: Soviet space program (in Soyuz spacecraft)
- 1966: Regional jet: Yakovlev
- 1967: Automatic Teller Machine: John Shepherd-Barron
- 1967: Automated space docking: Soviet space program (Kosmos 186 and Kosmos 188)
- 1967: Hypertext: Andries van Dam and Ted Nelson
- 1967: Quartz wristwatch: Seiko<sup>[264]</sup>
- 1967: FM synthesis: John Chowning
- 1967: Mumps vaccine: Maurice Hilleman
- 1967: Space toilet: Soviet space program (in Soyuz spacecraft)
- 1967: Venus lander: Soviet space program (Venera 4)
- 1968: Aperture grille: Sony
- 1968: Video game console: Ralph H. Baer
- 1968: Supersonic transport: Tupolev (Tupolev Tu-144) and Aérospatiale with British Aircraft Corporation (Concorde)
- 1969: ARPANET (first wide-area packet switching network): United States Department of Defense<sup>[19]</sup>
- 1969: Hypertext: Ted Nelson, Andries van Dam
- 1969: Digital Photography, charge coupled device Willard Boyle and George E. Smith<sup>[265]</sup>
- 1969: Video cassette: Sony
- Packet switching: Paul Baran and Donald Davies, independently

### 1970s

- 1970s: Radial keratotomy: Svyatoslav Fyodorov
- 1970: Pocket calculator: Sanyo, Canon, Sharp
- 1970: Relational database management system: Edgar F. Codd
- 1970: Space rover: Soviet space program (Alexander Kemurdzhian)
- 1971: Space station: Soviet space program (Vladimir Chelomey, Kerim Kerimov and others)<sup>[258]</sup> <sup>[266]</sup>
- 1971: E-mail: Ray Tomlinson<sup>[267]</sup>
- 1971: Karaoke: Daisuke Inoue
- 1971: Liquid Crystal Display: James Fergason
- 1971: Microprocessor: Masatoshi Shima, Federico Faggin, Ted Hoff
- 1971: Pocket calculator: Sharp Corporation
- 1971: Magnetic resonance imaging: Raymond V. Damadian
- 1971: Oil-eating bacteria: Ananda Mohan Chakrabarty
- 1971: Videocassette recorder: Sony
- 1972: Computed tomography: Godfrey Newbold Hounsfield
- 1972: Magnavox Odyssey: Ralph Baer
- 1972: Hall effect thruster: Soviet space program

- 1973: Hybrid rice in China<sup>[268]</sup>
- 1973: Ethernet: Bob Metcalfe and David Boggs
- 1973: Genetically modified organism: Stanley Norman Cohen and Herbert Boyer
- 1973: Reflectron: Boris Mamyrin
- 1973: Personal computer: Xerox PARC
- 1974: Electron cooling: Gersh Budker
- 1974: Microfinance: Muhammad Yunus
- 1974: Rubik's Cube: Ernő Rubik
- 1974: Hybrid vehicle: Victor Wouk<sup>[269]</sup>
- 1975: Androgynous Peripheral Attach System: Soviet space program (Vladimir Syromyatnikov)
- 1975: DNA sequencing by chain termination Frederick Sanger
- 1975: Digital camera: Steven Sasson
- 1975: Underwater assault rifle: Vladimir Simonov
- 1976: Gore-Tex fabric: W. L. Gore & Associates
- 1976: Mobile ICBM: Alexander Nadiradze
- 1976: Perpendicular recording: Shun-ichi Iwasaki at Tohoku University
- 1977: Personal stereo: Andreas Pavel
- 1977: Mobile phone: Bell Labs<sup>[270]</sup>
- 1978: Credit-card-sized calculator: Casio
- 1978: Solar-powered calculator: Sharp
- 1978: Spreadsheet: Dan Bricklin
- 1979: Walkman: Sony
- 1979: Solid state digital audio player Kane Kramer

## 1980s

- 1980: Compact Disc: Sony Corp, Philips Electronics<sup>[19]</sup>
- 1980: Flash memory: Fujio Masuoka<sup>[271]</sup> <sup>[272]</sup>
- 1981: WIMP graphical User Interface (GUI): Xerox PARC
- 1981: Handheld electronic camera: Sony
- 1981: Scanning tunneling microscope: Gerd Karl Binnig and Heinrich Rohrer
- 1981: Video Floppy: Sony
- 1982: Compact Disc player: Sony<sup>[273]</sup>
- 1982: Insulated gate bipolar transistor: Hans Becke and Carl Wheatley RCA
- 1982: ACE inhibitor: John R. Vane
- 1982: Artificial heart: Robert Jarvik, incorporating modifications to earlier experimental designs
- 1982: Camcorder: Sony
- 1982: D-pad: Gunpei Yokoi
- 1982 (date of first marketing): Pocket television: Sony<sup>[274]</sup>
- 1982: Flat panel display: Sony
- 1982: Parallax scrolling: Irem<sup>[275]</sup>
- 1983: Personal digital assistant: Casio
- 1983: Internet: first TCP/IP network by Robert E. Kahn, Vint Cerf and others
- 1983: Color LCD television: Seiko<sup>[276]</sup> <sup>[277]</sup>
- 1984: Portable CD player: Sony
- 1984: Phase distortion synthesis: Casio
- 1984: Lithotripsy: Claude Dornier
- 1985: Graphing calculator: Casio

- 1985: Polymerase chain reaction: Kary Mullis
- 1985: DNA fingerprinting: Alec Jeffreys
- 1986: Modular space station: Soviet space program (*Mir* space station)
- 1987: Statin, cholesterol drug: Carl Hoffman
- 1987: Digital Light Processing: Dr. Larry Hornbeck, Texas Instruments
- 1987: Electronically-controlled continuously variable transmission: Subaru
- 1988: Digital camera: Fuji
- 1989: Blue laser: Isamu Akasaki
- 1989: Digital waveguide synthesis: Yamaha, Stanford University
- 1989: Sildenafil (Viagra): Pfizer<sup>[278]</sup>
- 1989: Supermaneuverability: Sukhoi (Sukhoi Su-27 first performing Pugachev's Cobra)
- Digital Audio Tape: Sony
- PCM adaptor: Sony
- Vowel-Consonant synthesis: Casio

### 1990s

- 1990: World Wide Web: Tim Berners-Lee<sup>[19]</sup> <sup>[279]</sup>
- 1991: Memory card: Japan Electronic Industries Development Association
- 1991: Webcam: Quentin Stafford-Fraser Paul Jardetzky
- 1992: Plasma color display: Fujitsu
- 1993: Global Positioning System: United States Department of Defense
- 1993: Smart Phone: IBM
- 1993: Blue LED: Shuji Nakamura
- 1996: Force feedback: Nintendo
- 1996: Analog modeling synthesizer: Clavia DMI
- 1996: Universal Serial Bus(USB): A group of seven companies: Compaq, DEC, IBM, Intel, Microsoft, NEC and Nortel.
- 1997: Auto-Tune: Andy Hidebrand
- 1997: Non-mechanical mp3 digital audio player: SaeHan Information Systems<sup>[280]</sup>
- 1997: Plasma television: Pioneer Corporation
- 1998: Submarine-launched spacecraft: Russian Space Agency
- 1999: Digital Video Recorder: Tivo, ReplayTV
- 1999: Sea Launch: Igor Spassky (cooperation of the United States, Norway, Russia and Ukraine)

## 3rd millennium

### 21st century

#### 2000s

- 2000: Human genome sequencing process.<sup>[281]</sup>
  - 2000: Flashdrive: Trek Technology and IBM
  - 2002: Synthetic Life: Researchers at SUNY Stony Brook succeeded in synthesizing the 7741 base poliovirus from its published genetic sequence, producing the first synthetic organism
  - 2005: Orbitrap: Alexander Makarov<sup>[282]</sup>
  - 2006: Induced pluripotent stem cells: Shinya Yamanaka
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## References

- Alter, J. S. in "Kabaddi, a national sport of India". Dyck, Noel (2000). *Games, Sports and Cultures*. Berg Publishers: ISBN 1-85973-317-4.
- Asimov, Isaac, "Asimov's Chronology of Science and Discovery", Harper & Row, 1989. ISBN 0-06-015612-0
- Bedini, Silvio A. (1994). *The Trail of Time : Time Measurement with Incense in East Asia*. England: Cambridge University Press. ISBN 0-521-37482-0.
- Chamberlin, J. Edward (2007). *Horse: How the Horse Has Shaped Civilizations*. Moscow: Olma Media Group. ISBN 1-904955-36-3.
- Dales, George (1974), "Excavations at Balakot, Pakistan, 1973"<sup>[283]</sup>, *Journal of Field Archaeology* (Boston University) **1** (1–2): 3–22 [10], doi:10.2307/529703.
- Davreu, Robert (1978). "Cities of Mystery: The Lost Empire of the Indus Valley". *The World's Last Mysteries*. (second edition). Sydney: Readers' Digest. ISBN 0-909486-61-1
- De Bono, Edward, "Eureka! An Illustrated History of Inventions from the Wheel to the Computer", Thames & Hudson, 1974.
- Finger, Stanley (2001). *Origins of Neuroscience: A History of Explorations Into Brain Function*. England: Oxford University Press. ISBN 0-19-514694-8.
- Ghosh, Amalananda (1990). *An Encyclopaedia of Indian Archaeology*. Brill. ISBN 90-04-09264-1.
- Ghosh, S.; Massey, Reginald; and Banerjee, Utpal Kumar (2006). *Indian Puppets: Past, Present and Future*. Abhinav Publications. ISBN 81-7017-435-X.
- Gowlett, John, "Ascent to Civilization", McGraw-Hill, Inc., 1992. ISBN 0-07-544312-0
- Juleff, G. (1996), "An ancient wind powered iron smelting technology in Sri Lanka", *Nature* **379** (3): 60–63, doi:10.1038/379060a0.
- Koppel, Tom (2007). *Ebb and Flow: Tides and Life on Our Once and Future Planet*. Dundurn Press Ltd. ISBN 1-55002-726-3.
- Livingston, Morna & Beach, Milo (2002). *Steps to Water: The Ancient Stepwells of India*. Princeton Architectural Press. ISBN 1-56898-324-7.
- Needham, Joseph (1954–1986), *Science and Civilisation in China*, Cambridge University Press, ISBN 0521632625
- Platt, Richard, "Eureka!: Great Inventions and How They Happened", 2003.
- Pruthi, Raj (2004). *Prehistory and Harappan Civilization*. New Delhi: APH Publishing Corp. ISBN 81-7648-581-0.
- Schafer, Edward H. (1963). *The Golden Peaches of Samarkand: A Study of T'ang Exotics*. California: University of California Press. ISBN 0-520-05462-8.
- Srinivasan, S. & Ranganathan, S. *Wootz Steel: An Advanced Material of the Ancient World*. Bangalore: Indian Institute of Science.<sup>[284]</sup>
- Thrusfield, Michael (2007). *Veterinary Epidemiology*. Blackwell Publishing. ISBN 1-4051-5627-9.
- Whitelaw, Ian (2007). *A Measure of All Things: The Story of Man and Measurement*. Macmillan. ISBN 0-312-37026-1.
- Basch, Lucien (2001), "La voile latine, son origine, son évolution et ses parentés arabes", in Tzalas, H., *Tropis VI, 6th International Symposium on Ship Construction in Antiquity, Lamia 1996 proceedings*, Athens: Hellenic Institute for the Preservation of Nautical Tradition, pp. 55–85
- Campbell, I.C. (1995), "The Lateen Sail in World History"<sup>[285]</sup>, *Journal of World History* **6** (1): 1–23
- Casson, Lionel (1954), "The Sails of the Ancient Mariner", *Archaeology* **7** (4): 214–219
- Casson, Lionel (1995), *Ships and Seamanship in the Ancient World*, Johns Hopkins University Press, ISBN 0801851300
- Castro, F.; Fonseca, N.; Vacas, T.; Ciciliot, F. (2008), "A Quantitative Look at Mediterranean Lateen- and Square-Rigged Ships (Part 1)", *The International Journal of Nautical Archaeology* **37** (2): 347–359,

doi:10.1111/j.1095-9270.2008.00183.x

- Friedman, Zaraza; Zoroglu, Levent (2006), "Kelenderis Ship. Square or Lateen Sail?", *The International Journal of Nautical Archaeology* **35** (1): 108–116, doi:10.1111/j.1095-9270.2006.00091.x
- Makris, George (2002), "Ships", in Laiou, Angeliki E, *The Economic History of Byzantium. From the Seventh through the Fifteenth Century*, **2**, Dumbarton Oaks, pp. 89–99, ISBN 0-88402-288-9
- Pomey, Patrice (2006), "The Kelenderis Ship: A Lateen Sail", *The International Journal of Nautical Archaeology* **35** (2): 326–335, doi:10.1111/j.1095-9270.2006.00111.x
- Pryor, John H.; Jeffreys, Elizabeth M. (2006), *The Age of the ΔΡΟΜΩΝ: The Byzantine Navy ca. 500–1204*, Brill Academic Publishers, ISBN 978-9004151970
- White, Lynn (1978), "The Diffusion of the Lateen Sail", *Medieval Religion and Technology. Collected Essays*, University of California Press, pp. 255–260, ISBN 0-520-03566-6
- Whitewright, Julian (2009), "The Mediterranean Lateen Sail in Late Antiquity", *The International Journal of Nautical Archaeology* **38** (1): 97–104, doi:10.1111/j.1095-9270.2008.00213.x

## Notes

- [1] Hadfield, Peter, Gimme Shelter (<http://www.newscientist.com/channel/being-human/human-evolution/mg16522280.300-gimme-shelter.html>)
- [2] Gibbons, Ann (June 15, 2007), "Food for Thought: Did the first cooked meals help fuel the dramatic evolutionary expansion of the human brain?" ([http://files.meetup.com/254306/Food for Thought.pdf](http://files.meetup.com/254306/Food%20for%20Thought.pdf)), *Science* **316** (5831): 1558–1560, doi:10.1126/science.316.5831.1558, PMID 17569838, .
- [3] Earliest evidence of art found (<http://news.bbc.co.uk/1/hi/sci/tech/733747.stm>)
- [4] Kouwenhoven, Arlette P., World's Oldest Spears (<http://www.archaeology.org/9705/newsbriefs/spears.html>)
- [5] Evolving in their graves: early burials hold clues to human origins ([http://findarticles.com/p/articles/mi\\_m1200/is\\_24\\_160/ai\\_81827792/](http://findarticles.com/p/articles/mi_m1200/is_24_160/ai_81827792/))
- [6] Jennifer Viegas (31 March 2008). "Early Weapon Evidence Reveals Bloody Past" (<http://dsc.discovery.com/news/2008/03/31/earliest-weapon-human.html>). Discovery News. .
- [7] Neanderthal Bone Flute? (<http://cogweb.ucla.edu/ep/FluteDebate.html>), Cognitive Cultural Studies, UCLA. Accessed on line August 26, 2009.
- [8] Swaziland Natural Trust Commission, "Cultural Resources – Malolotja Archaeology, Lion Cavern", Retrieved March 10, 2010, SNTC.org.sz (<http://www.sntc.org.sz/cultural/malarch.asp>)
- [9] *Migration in world history*, p. 33, Patrick Manning
- [10] Balter M. (2009), "Clothes Make the (Hu) Man", *Science* **325** (5946): 1329, doi:10.1126/science.325\_1329a.
- [11] Kvavadze E, Bar-Yosef O, Belfer-Cohen A, Boaretto E, Jakeli N, Matskevich Z, Meshveliani T. (2009), "30,000-Year-Old Wild Flax Fibers", *Science* **325** (5946): 1359, doi:10.1126/science.1175404.
- [12] 'Oldest musical instrument' found (<http://news.bbc.co.uk/2/hi/science/nature/8117915.stm>), Pallab Ghosh, BBC News, June 25, 2009. Accessed on line August 26, 2009.
- [13] MSNBC : World's first dog lived 31,700 years ago, ate big (<http://www.msnbc.msn.com/id/27240370/>)
- [14] Small, Meredith F. (April 2002), "String theory: the tradition of spinning raw fibers dates back 28,000 years. (At The Museum).", *Natural History* **111.3**: 14(2)
- [15] J.C. Turner and P. van de Griend (ed.), *The History and Science of Knots* (Singapore: World Scientific, 1996), 14.
- [16] "Chinese pottery may be earliest discovered." ([http://www.cleveland.com/world/index.ssf/2009/06/chinese\\_pottery\\_may\\_be\\_earlies.html](http://www.cleveland.com/world/index.ssf/2009/06/chinese_pottery_may_be_earlies.html)) Associated Press. 2009-06-01
- [17] Stone age man used dentist drill (<http://news.bbc.co.uk/1/hi/sci/tech/4882968.stm>). BBC News.
- [18] Milk Drinking Started Around 7,500 Years Ago In Central Europe (<http://www.sciencedaily.com/releases/2009/08/090827202513.htm>), Science Daily, Sep. 1, 2009
- [19] Encyclopædia Britannica's Great Inventions (<http://corporate.britannica.com/press/inventions.html>), Encyclopædia Britannica
- [20] Kulke, Hermann & Rothermund, Dietmar (2004). *A History of India*. Routledge. 22. ISBN 0-415-32920-5.
- [21] Henderson, Mark (2007-12-24). "Dashing Finns were first to get their skates on 5,000 years ago" (<http://www.timesonline.co.uk/tol/news/uk/science/article3090363.ece>). London: The Times. . Retrieved 2007-12-24.
- [22] Carter, Robert "Boat remains and maritime trade in the Persian Gulf during the sixth and fifth millennia BC" *Antiquity* Volume 80 No.307 March 2006 Academia.edu ([http://oxfordbrookes.academia.edu/documents/0010/3548/Carter\\_Boats\\_Antiquity.pdf](http://oxfordbrookes.academia.edu/documents/0010/3548/Carter_Boats_Antiquity.pdf))
- [23] Thornton, C; Lamberg-Karlovsky, C; Liezers, M; Young, S. M. M. (2002), "On pins and needles: tracing the evolution of copper-based alloying at Tepe Yahya, Iran, via ICP-MS analysis of Common-place items", *Journal of Archaeological Science* **29**: 1451–1460, doi:10.1006/jasc.2002.0809.

- [24] Rodda & Ubertini (2004), *The Basis of Civilization—water Science?*, p. 161, International Association of Hydrological Science, ISBN 1-901502-57-0
- [25] Teresi, Dick; et al. (2002), *Lost Discoveries: The Ancient Roots of Modern Science—from the Babylonians to the Maya*, pp. 351–2, New York: Simon & Schuster, ISBN 0-684-83718-8
- [26] Kryss Katsiavriades and Talaat Qureshi, Inventions – 3000 BCE to 2000 BCE ([http://www.kryssstal.com/inventions\\_04.html](http://www.kryssstal.com/inventions_04.html)).
- [27] Ghosh, Massey, and Banerjee, page 14
- [28] Dales (1974)
- [29] Rao, S. R. (1985), *Lothal*, pp. 27–8, Archaeological Survey of India
- [30] Whitelaw, page 14
- [31] "Games and Amusement: Dice". *Encyclopedia of Indian Archaeology* edited by A. Ghosh (1990), 1: 178–179, Brill Academic Publishers, ISBN 90-04-09264-1
- [32] Bhardwaj, H.C. & Jain, K.K., "Indian Dyes and Industry During 18th–19th Century", *Indian Journal of History of Science*, **17** (11): 70–81, New Delhi: Indian National Science Academy.
- [33] Keay, John (2001), *India: A History*, 13–14, Grove Press, ISBN 0-8021-3797-0.
- [34] Thrusfield, page 2
- [35] Alter, page 88
- [36] Whitehouse, David (July 1, 1999). "World's oldest telescope?" (<http://news.bbc.co.uk/1/hi/sci/tech/380186.stm>). *BBC News*. . Retrieved May 10, 2008.
- [37] History of Ondol ([http://k.daum.net/qna/view.html?qid=3FhCO&l\\_cid=&l\\_st=](http://k.daum.net/qna/view.html?qid=3FhCO&l_cid=&l_st=))
- [38] A World of Glass (<http://www.sciencemag.org/cgi/content/full/305/5689/1407>)
- [39] Needham (1986), volume 6 part 5 105–106
- [40] Zaheer Baber (1996), *The Science of Empire: Scientific Knowledge, Civilization, and Colonial Rule in India*, p. 23, State University of New York Press, ISBN 0-7914-2919-9
- [41] p. 291, §15.2, *Understanding materials science: history, properties, applications*, Rolf E. Hummel, 2nd ed., Springer, 2004, ISBN 0-387-20939-5.
- [42] Koppel (2007), page 217
- [43] Dimitrakoudis, P. Papispyrou, V. Petoussis, X. Moussas: "Archaic artifacts resembling celestial spheres" (<http://scitation.aip.org/getabs/servlet/GetabsServlet?prog=normal&id=APCPCS000848000001000919000001&idtype=cvips&gifs=yes>)
- [44] Inventions 1000 BCE to 1 BCE ([http://www.kryssstal.com/inventions\\_06.html](http://www.kryssstal.com/inventions_06.html))
- [45] Finger (2001), page 66
- [46] Chamberlin (2007), page 80
- [47] Lynn Townsend White, Jr (1960), "Tibet, India, and Malaya as Sources of Western Medieval Technology", *The American Historical Review* **65** (3): 516.
- [48] Needham (1986), Volume 4, Part 2, 319–323.
- [49] *Encyclopædia Britannica* (2008), "Linguistics"
- [50] Stone-Hurling Catapult, Greece, 400 BCE ([http://www.smith.edu/hsc/museum/ancient\\_inventions/hsc11b.htm](http://www.smith.edu/hsc/museum/ancient_inventions/hsc11b.htm))
- [51] Joseph Needham (1986). *Science and Civilization in China: Volume 4, Part 2*, p. 361. Taipei: Caves Books, Ltd.
- [52] Srinivasan & Ranganathan
- [53] Juleff 1996
- [54] Ancient Roman Inventions ([http://www.mariamilani.com/ancient\\_rome/ancient\\_roman\\_inventions.htm](http://www.mariamilani.com/ancient_rome/ancient_roman_inventions.htm))
- [55] *MSN Encarta* (2007), *Diamond* ([http://encarta.msn.com/encyclopedia\\_761557986/Diamond.html](http://encarta.msn.com/encyclopedia_761557986/Diamond.html))
- [56] Lewis, Michael (2000), "Theoretical Hydraulics, Automata, and Water Clocks", in Wikander, Örjan, *Handbook of Ancient Water Technology*, Technology and Change in History, **2**, Leiden, pp. 343–369 (356f.), ISBN 90-04-11123-9
- [57] *Encyclopædia Britannica* (2008), "cashmere"
- [58] *Encyclopædia Britannica* (2008), "Pagoda"
- [59] Roman Inventions ([http://www.factsmonk.com/Roman\\_Inventions](http://www.factsmonk.com/Roman_Inventions))
- [60] Needham (1986), Volume 4, Part 2, 70–71.
- [61] Surgical Instruments from Ancient Rome ([http://www.healthsystem.virginia.edu/internet/library/wdc-lib/historical/artifacts/roman\\_surgical/](http://www.healthsystem.virginia.edu/internet/library/wdc-lib/historical/artifacts/roman_surgical/))
- [62] Roman period surgery set on show (<http://news.bbc.co.uk/2/hi/europe/7137224.stm>), BBC
- [63] Lynn Townsend White, Jr (1960), "Tibet, India, and Malaya as Sources of Western Medieval Technology", *The American Historical Review* **65** (3): 521.
- [64] Kriger, Colleen E. & Connah, Graham (2006), *Cloth in West African History*, p. 120, Rowman Altamira, ISBN 0-7591-0422-0
- [65] *Encyclopædia Britannica* (2008), "jute"
- [66] Needham (1986), Volume 4, Part 3, 649–650.
- [67] Casson 1995, pp. 243–245
- [68] Casson 1954
- [69] White 1978, p. 255
- [70] Campbell 1995, pp. 8–11

- [71] Basch 2001, pp. 63–64
- [72] Makris 2002, p. 96
- [73] Friedman & Zoroglu 2006, pp. 113–114
- [74] Pryor & Jeffreys 2006, pp. 153–161
- [75] Castro et al. 2008, pp. 1–2
- [76] Whitewright 2009
- [77] Zaheer Baber (1996), *The Science of Empire: Scientific Knowledge, Civilization, and Colonial Rule in India*, p. 57, State University of New York Press, ISBN 0-7914-2919-9
- [78] Paper – one of the most important inventions of the last two millennia ([http://www.baph.org.uk/general-reference/Paper - one of the most important inventions of the last two millennia.htm](http://www.baph.org.uk/general-reference/Paper-one-of-the-most-important-inventions-of-the-last-two-millennia.htm))
- [79] Livingston, Morna & Beach, Milo (2002), *Steps to Water: The Ancient Stepwells of India*, p. 19, Princeton Architectural Press, ISBN 1-56898-324-7
- [80] Hoepfner, Wolfram (1970), "Ein Kombinationsschloss aus dem Kerameikos", *Archäologischer Anzeiger* **85** (2): 210–213
- [81] Balasubramanian R. (2000), "On the Corrosion Resistance of the Delhi Iron Pillar" ([http://home.iitk.ac.in/~bala/journalpaper/journalpaper\\_17.pdf](http://home.iitk.ac.in/~bala/journalpaper/journalpaper_17.pdf)) (PDF), *Corrosion Science* **42**: 2103–29, doi:10.1016/S0010-938X(00)00046-9, .
- [82] Zaheer Baber (1996), *The Science of Empire: Scientific Knowledge, Civilization, and Colonial Rule in India*, pp. 56–7, State University of New York Press, ISBN 0-7914-2919-9
- [83] Ronald Watkins. *Unknown Seas*, p. 15.
- [84] Ancient Indian use of Kamal (<http://indiancalculus.info>)
- [85] Lynn Townsend White, Jr (1960), "Tibet, India, and Malaya as Sources of Western Medieval Technology", *The American Historical Review* **65** (3): 519.
- [86] John M. Hobson (2004), *The Eastern Origins of Western Civilisation*, p. 141, Cambridge University Press, ISBN 0-521-54724-5.
- [87] *Encyclopædia Britannica* (2002), "Chess: Ancient precursors and related games"
- [88] MSN Encarta (2008). *Pachisi* ([http://encarta.co.uk/encyclopedia\\_781530306/Pachisi.html](http://encarta.co.uk/encyclopedia_781530306/Pachisi.html)).
- [89] Schafer (1963), pages 160–161
- [90] Bedini (1994), pages 69–80
- [91] The history of gusli. ([http://altay-bulgaria.com/index.php?option=com\\_content&view=article&id=171:2008-11-16-16-54-54&catid=68:music&Itemid=1](http://altay-bulgaria.com/index.php?option=com_content&view=article&id=171:2008-11-16-16-54-54&catid=68:music&Itemid=1)) (**Russian**)
- [92] Gaudiosi, Monica M. (April 1988), "The Influence of the Islamic Law of Waqf on the Development of the Trust in England: The Case of Merton College" (<http://jstor.org/stable/3312162>), *University of Pennsylvania Law Review* (The University of Pennsylvania Law Review) **136** (4): 1231–1261, doi:10.2307/3312162,
- [93] Hudson, A. (2003), *Equity and Trusts* (3rd ed.), London: Cavendish Publishing, ISBN 1-85941-729-9
- [94] Dick, Michael S. (1998). The Ancient Ayurvedic Writings ([http://www.ayurveda.com/online\\_resource/ancient\\_writings.htm](http://www.ayurveda.com/online_resource/ancient_writings.htm)). Retrieved May 19, 2005.
- [95] Ahmad Y Hassan, Alcohol and the Distillation of Wine in Arabic Sources (<http://www.history-science-technology.com/Notes/Notes7.htm>).
- [96] Hassan, Ahmad Y. "Technology Transfer in the Chemical Industries" (<http://www.history-science-technology.com/Articles/articles72.htm>). Ahmad Y Hassan. . Retrieved 2008-05-26.
- [97] Derewenda, Zygmunt S. (2007), "On wine, chirality and crystallography", *Acta Crystallographica Section A: Foundations of Crystallography* **64** (Pt 1): 246–258 [247], doi:10.1107/S0108767307054293, PMID 18156689
- [98] Khairallah, Amin A. *Outline of Arabic Contributions to Medicine*, chapter 10. Beirut, 1946.
- [99] Information taken from the abstract of Hadzović, S (1997), "Pharmacy and the great contribution of Arab-Islamic science to its development" (in Croatian), *Medicinski arhiv* **51** (1–2): 47–50, ISSN 0350-199X, OCLC 32564530, PMID 9324574.
- [100] Dr. Kasem Ajram (1992). *Miracle of Islamic Science*, Appendix B. Knowledge House Publishers. ISBN 0-911119-43-4.
- [101] Ibrahim B. Syed PhD, "Islamic Medicine: 1000 years ahead of its times", *Journal of the Islamic Medical Association* **2002** (2): 2–9 [7–8].
- [102] Deborah Rowe, How Islam has kept us out of the 'Dark Ages' (<http://www.channel4.com/science/microsites/S/science/society/islamicscience2.html>), *Science and Society, Channel 4*, May 2004.
- [103] C. Wayne Smith, Joe Tom Cothren (1999), *Cotton: Origin, History, Technology, and Production*, p. viii, John Wiley and Sons. Technology & Industrial Arts, ISBN 0-471-18045-9
- [104] David A. King, "Islamic Astronomy", in Christopher Walker (1999), ed., *Astronomy before the telescope*, p. 167-168. British Museum Press. ISBN 0-7141-2733-7.
- [105] Salma Khadra Jayyusi and Manuela Marin (1994), *The Legacy of Muslim Spain*, p. 117, Brill Publishers, ISBN 90-04-09599-3
- [106] Lebling Jr., Robert W. (July–August 2003), "Flight of the Blackbird" (<http://www.saudiaramcoworld.com/issue/200407/flight.of.the.blackbird-compilation.htm>), *Saudi Aramco World*: 24–33, , retrieved 2008-06-28
- [107] Koetsier Teun (2001), "On the prehistory of programmable machines: musical automata, looms, calculators", *Mechanism and Machine theory* **36**: 590–591.
- [108] Donald Routledge Hill, "Mechanical Engineering in the Medieval Near East", *Scientific American*, May 1991, p. 64-69. (cf. Donald Routledge Hill, Mechanical Engineering (<http://home.swipnet.se/islam/articles/HistoryofSciences.htm>))



- [109] Fowler, Charles B. (October 1967), "The Museum of Music: A History of Mechanical Instruments" (<http://jstor.org/stable/3391092>), *Music Educators Journal* (MENC\_ The National Association for Music Education) **54** (2): 45–49, doi:10.2307/3391092,
- [110] Muslin ([http://banglapedia.search.com.bd/HT/M\\_0427.htm](http://banglapedia.search.com.bd/HT/M_0427.htm)), *Banglapedia*. Asiatic Society of Bangladesh (2008)
- [111] Ahmad, S. (July–September 2005), "Rise and Decline of the Economy of Bengal", *Asian Affairs* **27** (3): 5–26
- [112] Mason, Robert B. (1995), "New Looks at Old Pots: Results of Recent Multidisciplinary Studies of Glazed Ceramics from the Islamic World", *Muqarnas: Annual on Islamic Art and Architecture* (Brill Academic Publishers) **XII**: 5, ISBN 90-04-10314-7.
- [113] David A. King, "Islamic Astronomy", pp. 168–169
- [114] King, David A. (2005), *In Synchrony with the Heavens, Studies in Astronomical Timekeeping and Instrumentation in Medieval Islamic Civilization: Instruments of Mass Calculation*, Brill Publishers, ISBN 900414188X
- [115] King, David A. (December 2003), "14th-Century England or 9th-Century Baghdad? New Insights on the Elusive Astronomical Instrument Called Navicula de Venetiis", *Centaurus* **45** (1–4): 204–226, doi:10.1111/j.1600-0498.2003.450117.x
- [116] Ahmad Y Hassan, Donald Routledge Hill (1986). *Islamic Technology: An illustrated history*, p. 54. Cambridge University Press. ISBN 0-521-42239-6.
- [117] Alatas, Syed Farid (2006), "From Jami`ah to University: Multiculturalism and Christian–Muslim Dialogue", *Current Sociology* **54** (1): 112–132 [123–4], doi:10.1177/0011392106058837
- [118] Adam Lucas (2006), *Wind, Water, Work: Ancient and Medieval Milling Technology*, p. 65. BRILL, ISBN 90-04-14649-0.
- [119] Bulliet Richard W. (1987), "Medieval Arabic Tarsh: A Forgotten Chapter in the History of Printing" (<http://jstor.org/stable/603463>), *Journal of the American Oriental Society* **107** (3): 427–438, doi:10.2307/603463, .
- [120] F. L. Lewis (1992), *Applied Optimal Control and Estimation*, Englewood Cliffs, Prentice-Hall, New Jersey.
- [121] Gari L. (2002), "Arabic Treatises on Environmental Pollution up to the End of the Thirteenth Century", *Environment and History* **8** (4): 475–488, doi:10.3197/096734002129342747.
- [122] Lynn Townsend White, Jr (1961), "Eilmer of Malmesbury, an Eleventh Century Aviator: A Case Study of Technological Innovation, Its Context and Tradition" (<http://jstor.org/stable/3101411>), *Technology and Culture* **2** (2): 97–111 [100–101], doi:10.2307/3101411, .
- [123] Ismail b. Ali Ebu'l Feda history, *Weltgeschichte*, hrsg. von Fleischer and Reiske 1789–94, 1831.
- [124] Dayela, A. Al; al-Zuhair, N. (2006), "Single drug therapy in the treatment of male sexual/erectile dysfunction in Islamic medicine", *Urology* **68** (1): 253–4, doi:10.1016/j.urology.2006.08.748.
- [125] Regis Morelon, "General Survey of Arabic Astronomy", pp. 9–10, in Rashed, Roshdi; Morelon, Régis (1996), *Encyclopedia of the History of Arabic Science*, **1 & 3**, Routledge, pp. 1–19, ISBN 0415124107
- [126] Alatas, Syed Farid (2006), "From Jami`ah to University: Multiculturalism and Christian–Muslim Dialogue", *Current Sociology* **54** (1): 112–32, doi:10.1177/0011392106058837
- [127] *The Guinness Book Of Records*, 1998, p. 242, ISBN 0-553-57895-2
- [128] First Flights (<http://www.saudiaramcoworld.com/issue/196401/first.flights.htm>), *Saudi Aramco World*, January–February 1964, p. 8-9.
- [129] Zayn Bilkadi (University of California, Berkeley), "The Oil Weapons", *Saudi Aramco World*, January–February 1995, p. 20-27.
- [130] Donald Routledge Hill (1996), "Engineering", p. 783, in Rashed, Roshdi; Morelon, Régis (1996), *Encyclopedia of the History of Arabic Science*, **1 & 3**, Routledge, pp. 751–95, ISBN 0415124107
- [131] David J Roxburgh (2000), *Muqarnas: An Annual on the Visual Culture of the Islamic World*, p. 21, Brill Publishers, ISBN 90-04-11669-9.
- [132] Josef W. Meri (2006), *Medieval Islamic Civilization: An Encyclopedia*, p. 75, Taylor and Francis, ISBN 0-415-96691-4.
- [133] David A. King (1999), *World-maps for Finding the Direction and Distance to Mecca: Innovation and Tradition in Islamic Science*, p. 17, Brill Publishers, ISBN 90-04-11367-3.
- [134] Paul Vallyely, How Islamic Inventors Changed the World (<http://www.independent.co.uk/news/science/how-islamic-inventors-changed-the-world-469452.html>), *The Independent*, 11 March 2006.
- [135] Bosworth, C. E. (Autumn 1981), "A Mediaeval Islamic Prototype of the Fountain Pen?", *Journal of Semitic Studies* **XXVI** (i)
- [136] The history of kvas (<http://www.kvas.ru/history.htm>) at kvas.ru site (**Russian**)
- [137] Russian Church Design (<http://www.strangelove.net/~kieser/Russia/churches.html>) by Lisa Kies.
- [138] About Russian Domes and Cupolas ([http://www.skypalace.org/europe/slavic/east\\_slavic/russia/articles/domes.shtml](http://www.skypalace.org/europe/slavic/east_slavic/russia/articles/domes.shtml)) at Sky Palace world architecture site.
- [139] O'Connor, John J.; Robertson, Edmund F., "Abu Mahmud Hamid ibn al-Khidr Al-Khujandi" (<http://www-history.mcs.st-andrews.ac.uk/Biographies/Al-Khujandi.html>), *MacTutor History of Mathematics archive*, University of St Andrews, .
- [140] "Islam, Knowledge, and Science" ([http://www.usc.edu/dept/MSA/introduction/woi\\_knowledge.html](http://www.usc.edu/dept/MSA/introduction/woi_knowledge.html)). University of Southern California. . Retrieved 2008-01-22.
- [141] Dekker Elly (1995), "An unrecorded medieval astrolabe quadrant from c. 1300", *Annals of Science* **52** (1): 1–47 [6], doi:10.1080/00033799500200101.
- [142] Donald Routledge Hill (1996), "Engineering", p. 766-9, in Rashed, Roshdi; Morelon, Régis (1996), *Encyclopedia of the History of Arabic Science*, Routledge, pp. 751–795, ISBN 0415124107
- [143] Donald Routledge Hill (1996), "Engineering", p. 781, in Rashed, Roshdi; Morelon, Régis (1996), *Encyclopedia of the History of Arabic Science*, Routledge, pp. 751–95, ISBN 0415124107
- [144] Fielding H. Garrison, *History of Medicine*:

"The Saracens themselves were the originators not only of algebra, chemistry, and geology, but of many of the so-called improvements or refinements of civilization, such as street lamps, window-panes, firework, stringed instruments, cultivated fruits, perfumes, spices, etc..."

- [145] The World's First Soft Drink. (<http://www.1001inventions.com/index.cfm?fuseaction=main.viewBlogEntry&intMTEEntryID=2889>) 1001 Inventions, 2006.
- [146] Juliette Rossant (2005), The World's First Soft Drink (<http://www.saudiaramcoworld.com/issue/200505/the.world.s.first.soft.drink.htm>), *Saudi Aramco World*, September/October 2005, pp. 36–9
- [147] Peter Barrett (2004), *Science and Theology Since Copernicus: The Search for Understanding*, p. 18, Continuum International Publishing Group, ISBN 0-567-08969-X.
- [148] Micheau, Françoise, "The Scientific Institutions in the Medieval Near East", pp. 988–991 in Morelon, Régis; Rashed, Roshdi (1996), *Encyclopedia of the History of Arabic Science*, **3**, Routledge, pp. 985–1007, ISBN 0415124107
- [149] Ibrahim B. Syed PhD (2002), "Islamic Medicine: 1000 years ahead of its times", *Journal of the International Society for the History of Islamic Medicine* **2**: 2–9 [7].
- [150] Finger, Stanley (1994), *Origins of Neuroscience: A History of Explorations Into Brain Function*, Oxford University Press, p. 70, ISBN 0195146948
- [151] Ancient surgery (<http://www.channel4.com/history/microsites/H/history/a-b/ancientsurgery7.html>)
- [152] Zafarul-Islam Khan, At The Threshold (sic) Of A New Millennium – II (<http://milligazette.com/Archives/15-1-2000/Art5.htm>), *The Milli Gazette*.
- [153] Abdul Nasser Kaadan PhD, "Albucasis and Extraction of Bladder Stone", *Journal of the International Society for the History of Islamic Medicine* **2004** (3): 28–33.
- [154] Sigrid Hunke (1969), *Allah Sonne Uber Abendland, Unser Arabische Erbe*, Second Edition, p. 279-280:
- "The science of medicine has gained a great and extremely important discovery and that is the use of general anaesthetics for surgical operations, and how unique, efficient, and merciful for those who tried it the Muslim anaesthetic was. It was quite different from the drinks the Indians, Romans and Greeks were forcing their patients to have for relief of pain. There had been some allegations to credit this discovery to an Italian or to an Alexandrian, but the truth is and history proves that, the art of using the anaesthetic sponge is a pure Muslim technique, which was not known before. The sponge used to be dipped and left in a mixture prepared from cannabis, opium, hyoscyamus and a plant called Zoan."
- (cf. Prof. Dr. M. Taha Jasser, Anaesthesia in Islamic medicine and its influence on Western civilization ([http://www.islamset.com/hip/i\\_medicin/taha\\_jasser.html](http://www.islamset.com/hip/i_medicin/taha_jasser.html)), Conference on Islamic Medicine)
- [155] Patricia Skinner (2001), Unani-tibbi ([http://findarticles.com/p/articles/mi\\_g2603/is\\_0007/ai\\_2603000716](http://findarticles.com/p/articles/mi_g2603/is_0007/ai_2603000716)), *Encyclopedia of Alternative Medicine*
- [156] Seyyed Hossein Nasr (1993), *An Introduction to Islamic Cosmological Doctrines*, pp. 135–6, State University of New York Press, ISBN 0-7914-1516-3
- [157] Marlene Ericksen (2000). *Healing with Aromatherapy*, p. 9. McGraw-Hill Professional. ISBN 0-658-00382-8.
- [158] Will Durant (1950). *The Story of Civilization IV: The Age of Faith*, p. 239-45.
- [159] Hall Robert E. (1973), "Al-Khazini", *Dictionary of Scientific Biography* **VII**: 346.
- [160] Marshall Clagett (1961). *The Science of Mechanics in the Middle Ages*, p. 64. University of Wisconsin Press.
- [161] Donald Routledge Hill (1985), "Al-Biruni's mechanical calendar", *Annals of Science* **42**: 139–163, doi:10.1080/00033798500200141.
- [162] Islam, Knowledge, and Science. ([http://web.archive.org/web/20070923081831/http://www.usc.edu/dept/MSA/introduction/woi\\_knowledge.html](http://web.archive.org/web/20070923081831/http://www.usc.edu/dept/MSA/introduction/woi_knowledge.html)) University of Southern California.
- [163] Kriss, Timothy C.; Kriss, Vesna Martich (April 1998), "History of the Operating Microscope: From Magnifying Glass to Microneurosurgery", *Neurosurgery* **42** (4): 899–907, doi:10.1097/00006123-199804000-00116, PMID 9574655
- [164] Wade Nicholas J., Finger Stanley (2001), "The eye as an optical instrument: from camera obscura to Helmholtz's perspective", *Perception* **30** (10): 1157–1177, doi:10.1068/p3210, PMID 11721819.
- [165] Tyler, Royall (2003), *The Tale of Genji*, Penguin Classics, pp. i–ii & xii, ISBN 014243714X
- [166] Tyler, Royall (2003), *The Tale of Genji*, Penguin Classics, p. xxvi, ISBN 014243714X
- [167] Tekol Yalcin (2007), "The medieval physician Avicenna used an herbal calcium channel blocker, *Taxus baccata* L.", *Phytotherapy Research* **21** (7): 701–2, doi:10.1002/ptr.2173, PMID 17533639.
- [168] Dr. A. Zahoor (1997). Al-Zarqali (Arzachel) (<http://www.unhas.ac.id/~rhiza/saintis/zarqali.html>), University of Indonesia.
- [169] Sivin (1995), III, 22.
- [170] Ebrey, Walthall, and Palais (2006), 162.
- [171] Ahmad Y Hassan, Flywheel Effect for a *Saqiya* (<http://www.history-science-technology.com/Notes/Notes 4.htm>).
- [172] Glick, Thomas F.; Livesey, Steven John; Wallis, Faith (2005), *Medieval Science, Technology, and Medicine: An Encyclopedia*, Routledge, p. 30, ISBN 0415969301
- [173] Encyclopædia Britannica (2008). *calico*

- [174] Ahmad Y Hassan, *Transfer Of Islamic Technology To The West, Part II: Transmission Of Islamic Engineering* (<http://www.history-science-technology.com/Articles/articles 71.htm>), *History of Science and Technology in Islam*.
- [175] Lorch, R. P. (1976), "The Astronomical Instruments of Jabir ibn Aflah and the Torquetum", *Centaurus* **20** (1): 11–34, doi:10.1111/j.1600-0498.1976.tb00214.x
- [176] Harding, David (1990), *Weapons: An International Encyclopedia from 5000 B.C. to 2000 A.D.* (<http://books.google.com/?id=LeYSxhK62wUC&printsec=frontcover#PPA111,M1>), Diane Publishing Company, p. 111, ISBN 0756784360,
- [177] Linear astrolabe (<http://www.britannica.com/eb/topic-342088/linear-astrolabe>), *Encyclopædia Britannica*.
- [178] Scott Farrell, *Weaponry: The Trebuchet* ([http://www.historynet.com/wars\\_conflicts/weaponry/3823351.html?page=2&c=y](http://www.historynet.com/wars_conflicts/weaponry/3823351.html?page=2&c=y))
- [179] Philip Daileader, *On the Social Origins of Medieval Institutions* (<http://books.google.com/books?id=OVX8j0zR6QYC>)
- [180] Jim Bradbury, *Medieval Siege* (<http://books.google.com/books?id=fKFRvUiLEQYC>)
- [181] 101 gadgets that changed the world (<http://www.independent.co.uk/life-style/gadgets-and-tech/features/101-gadgets-that-changed-the-world-398535.html>)
- [182] Moreno, Roberto; Koenraad, Koenraad; Cleempoel, Van; King, David (2002), "A Recently Discovered Sixteenth-Century Spanish Astrolabe", *Annals of Science* **59** (4): 331–362 [333], doi:10.1080/00033790110095813.
- [183] ANTIQUES; To Reflect On Or Simply To Admire (<http://query.nytimes.com/gst/fullpage.html?res=9906E2DB163DF934A15754C0A9679C8B63&sec=&spon=&pagewanted=all>)
- [184] Bedini Silvio A., Maddison Francis R. (1966), "Mechanical Universe: The Astrarium of Giovanni de' Dondi" (<http://jstor.org/stable/1006002>), *Transactions of the American Philosophical Society* **56** (5): 1–69, doi:10.2307/1006002, .
- [185] Kennedy, Edward S. (1962), "Review: *The Observatory in Islam and Its Place in the General History of the Observatory* by Aydin Sayili", *Isis* **53** (2): 237–239, doi:10.1086/349558
- [186] Hassan, Ahmad Y. "Gunpowder Composition for Rockets and Cannon in Arabic Military Treatises In Thirteenth and Fourteenth Centuries" (<http://www.history-science-technology.com/Articles/articles 2.htm>). Ahmad Y Hassan. . Retrieved 2008-06-08.
- [187] Savage-Smith Emilie (1988), "Gleanings from an Arabist's Workshop: Current Trends in the Study of Medieval Islamic Science and Medicine", *Isis* **79** (2): 246–266 [263], doi:10.1086/354701.
- [188] Cambridge University Press, ISBN 0-521-54724-5.
- [189] The shapes of domes of ancient Russian churches (<http://www.rusarch.ru/zagraevsky1.htm>) by Sergey Zagraevsky at the site of RusArch.ru (**Russian**)
- [190] The study of the history of ancient ploughs of the Novgorod land (<http://bibliotekar.ru/rusNovgorod/86.htm>) by V. Ya. Konetsky. (**Russian**)
- [191] Augustyn, pages 27–28
- [192] Tibbetts G. R. (1973), "Comparisons between Arab and Chinese Navigational Techniques", *Bulletin of the School of Oriental and African Studies* **36** (1): 97–108 [105–6], doi:10.1017/S0041977X00098013.
- [193] Kennedy E. S. (1947), "Al-Kashi's Plate of Conjunctions", *Isis* **38** (1–2): 56–59 [56], doi:10.1086/348036.
- [194] Kennedy E. S. (1952), "A Fifteenth-Century Planetary Computer: al-Kashi's Tabaq al-Maneteq II: Longitudes, Distances, and Equations of the Planets", *Isis* **43** (1): 42–50, doi:10.1086/349363.
- [195] Kennedy E. S. (1951), "An Islamic Computer for Planetary Latitudes" (<http://jstor.org/stable/595221>), *Journal of the American Oriental Society* **71** (1): 13–21, doi:10.2307/595221, .
- [196] Ahmad Y Hassan (1976). *Taqi al-Din and Arabic Mechanical Engineering*, p. 34-35. Institute for the History of Arabic Science, University of Aleppo.
- [197] Routledge Hill, Donald, Roshdi Rashed, ed., "Engineering", *Encyclopedia of the History of Arabic Science* (London and New York: Routledge) **2**: 751–795.
- [198] pencil (<http://www.britannica.com/eb/article-9059044/pencil>), Encyclopædia Britannica
- [199] Habib Irfan (1992), "Akbar and Technology" (<http://jstor.org/stable/3517712>), *Social Scientist* **20** (9–10): 3–15 [3–4], doi:10.2307/3517712, .
- [200] Rousselet (1875), page 290
- [201] Sivaramakrishnan (2001), pages 4–5
- [202] Blechynden (1905), page 215
- [203] Savage-Smith, Emilie (1985), *Islamicate Celestial Globes: Their history, Construction, and Use*, Smithsonian Institution Press, Washington, D.C.
- [204] American Physical Society – This Month in Physics – History Lens Crafters Circa 1590: Invention of the Microscope (<http://www.aps.org/publications/apsnews/200403/history.cfm>)
- [205] Old Walled City of Shibam (<http://whc.unesco.org/en/list/192>), UNESCO World Heritage Centre
- [206] galileo.rice.edu **The Galileo Project > Science > The Telescope** by Al Van Helden "*The Hague discussed the patent applications first of Hans Lipperhey of Middelburg, and then of Jacob Metius of Alkmaar... another citizen of Middelburg, Sacharias Janssen had a telescope at about the same time but was at the Frankfurt Fair where he tried to sell it*" (<http://galileo.rice.edu/sci/instruments/telescope.html>)
- [207] pp. 55–65, *The Origins of Feedback Control*, Otto Mayr, MIT Press, 1970, ISBN 0-262-13067-X.
- [208] "1679–1681 – R P Verbiest's Steam Chariot" ([http://translate.google.com/translate?hl=en&sl=fr&u=http://users.skynet.be/tintinpassion/VOIRSAVOIR/Auto/Pages\\_auto/Auto\\_001.html&sa=X&oi=translate](http://translate.google.com/translate?hl=en&sl=fr&u=http://users.skynet.be/tintinpassion/VOIRSAVOIR/Auto/Pages_auto/Auto_001.html&sa=X&oi=translate)). *History of the Automobile: origin to 1900*. Hergé. . Retrieved 2009-05-08.

- [209] Setright, L. J. K. (2004), *Drive On!: A Social History of the Motor Car*, Granta Books, ISBN 1-86207-698-7
- [210] Principles of helicopter aerodynamics (<http://books.google.ru/books?id=nMV-TkaX-9cC&lpq=PA13&ots=CodTn9WMfz&pg=PA7#v=onepage&q&f=false>) by J. Gordon Leishman, p. 7.
- [211] Roddam Narasimha (1985), *Rockets in Mysore and Britain, 1750–1850 A.D.* ([http://nal-ir.nal.res.in/2382/01/tr\\_pd\\_du\\_8503\\_R66305.pdf](http://nal-ir.nal.res.in/2382/01/tr_pd_du_8503_R66305.pdf)), National Aeronautical Laboratory and Indian Institute of Science
- [212] Conveyor technology: Elevator (<http://conveyor-tech.com/dictionary/catalog/10/index.html>) at conveyor-tech.com
- [213] Todd, Jan (1995). *From Milo to Milo: A History of Barbells, Dumbbells, and Indian Clubs* (<http://www.aafila.org/SportsLibrary/IGH/IGH0306/IGH0306c.pdf>). Accessed in September 2008. Hosted on the LA84 Foundation Sports Library.
- [214] James Burke (science historian) Connections – Episode 4 – "Faith in Numbers"
- [215] p. 159, *Concepts of Chemical Dependency*, Harold E. Doweiko, 7th ed., Cengage Learning, 2008, ISBN 0-495-50580-3.
- [216] Acott, Chris (1999), "JS Haldane, JBS Haldane, L Hill, and A Siebe: A brief resume of their lives." (<http://archive.rubicon-foundation.org/6016>), *South Pacific Underwater Medicine Society journal* **29** (3), ISSN 0813-1988, OCLC 16986801, , retrieved 2009-04-21.
- [217] The history of galvanopating in Russia ([http://www.galteh.ru/article\\_galvanotehnika.html](http://www.galteh.ru/article_galvanotehnika.html)) (**Russian**)
- [218] The question about the world's first oil well (<http://persona-rig.ru/index.php?page=81>) (**Russian**)
- [219] Connors; Dupuis & Morgan (1992) "Badminton" from *The Olympics Factbook*. Page 195
- [220] Guillain (2004), page 47
- [221] p. 456, "Heroin", Maria Theresa Wessel, Jeanne Martino-McAllister, and Elizabeth C. Gallon, in *Encyclopedia of Substance Abuse Prevention, Treatment, and Recovery*, Gary L. Fisher and Nancy A. Roget, SAGE, 2008, ISBN 1-4129-5084-8.
- [222] Quick, D. (1970), "A History Of Closed Circuit Oxygen Underwater Breathing Apparatus" (<http://archive.rubicon-foundation.org/4960>), *Royal Australian Navy, School of Underwater Medicine*. **RANSUM-1-70**, , retrieved 2009-03-16.
- [223] Maxim's 1884 Prototype Automatic Rifle (<http://www.glennhyatt.com/usmcguns/maxno1.htm>) Based on definition as being fully-automatic. James Puckle in 1718 made a "multi shot gun" that has been called a "machine gun" but not automatic, more like a revolver. Richard Gatling's 1861 Gatling Gun hand cranked so is a 'semi-automatic machine gun'
- [224] DE patent 36423 (<http://v3.espacenet.com/textdoc?DB=EPODOC&IDX=DE36423>), Gottlieb Daimler, "Fahrzeug mit gas bezw. Petroleum Kraftmaschine", issued 1885-11-29
- [225] §4.1, Neurochemical and Neurobehavioral Consequences of Methamphetamine Abuse, Colin N. Haile, chapter 4 in *Neurochemistry of abused drugs*, Steven B. Karch, ed., CRC Press, 2007, ISBN 1-4200-5441-4.
- [226] George Eastman: The Invention of the Kodak Hand-Held Camera (<http://www.juliantrubin.com/bigten/eastmancamera.html>)
- [227] Anderson, L. I., "John Stone Stone on Nikola Tesla's Priority in Radio and Continuous Wave Radiofrequency Apparatus". *The Antique Wireless Association Review*, Vol. 1, 1986.
- [228] A. K. Sen (1997). "Sir J.C. Bose and radio science", *Microwave Symposium Digest 2* (8–13), p. 557-560
- [229] Nagai N. (1893), "Kanyaku maou seibun kenkyuu seiseki (zoku)", *Yakugaku Zashi* **13**: 901.
- [230] History of Property Rights – Ikeda, Kikunae ([http://www.jpo.go.jp/seido\\_e/rekishi\\_e/kikunae\\_ikeda.htm](http://www.jpo.go.jp/seido_e/rekishi_e/kikunae_ikeda.htm))
- [231] Ikeda K (November 2002), "New seasonings" (<http://chemse.oxfordjournals.org/cgi/pmidlookup?view=long&pmid=12438213>), *Oxford Journal* **27** (9): 847–9, doi:10.1093/chemse/27.9.847, PMID 12438213, . (partial translation of Ikeda, Kikunae (1909), "New Seasonings[japan.]", *Journal of the Chemical Society of Tokyo* **30**: 820–836.)
- [232] "Jagadis Bose Research on Measurement of Plant Growth" (<http://www.edsanders.com/bose>). . Retrieved 2008-08-05.
- [233] Tokyo Kagaku Kaishi (1911) ([http://www.journalarchive.jst.go.jp/english/jnlabstract\\_en.php?cdjournal=nikkashi1880&cdvol=32&noissue=1&startpage=4](http://www.journalarchive.jst.go.jp/english/jnlabstract_en.php?cdjournal=nikkashi1880&cdvol=32&noissue=1&startpage=4))
- [234] "Benefit to humanity" ([http://fi.edu/case\\_files/coolidge\\_2853/merit.html](http://fi.edu/case_files/coolidge_2853/merit.html))
- [235] Who Invented The Tank? (<http://www.tankmuseum.co.uk/visfaq2.html>) – Bovington Tank Museum
- [236] Narlikar, J. V. (2002), *An Introduction to Cosmology*, p. 188, Cambridge University Press, ISBN 0-521-79376-9
- [237] "Non-Stop Shuttle Change Toyoda Automatic Loom, Type G" ([http://www.jsme.or.jp/kikaiisan/data/no\\_016.html](http://www.jsme.or.jp/kikaiisan/data/no_016.html)) (in Japanese). The Japan Society of Mechanical Engineers. .
- [238] *Encyclopædia Britannica* (2008), "Raman effect"
- [239] *Shanti Swarup Bhatnagar* (<http://www.vigyanprasar.gov.in/scientists/ssbhatnagar/ShantiSwarupBhatnagar.htm>). Vigyan Prasar: Government of India.
- [240] Stereoscopic TV (<http://www.bairdtelevision.com/stereo.html>)
- [241] Ten Japanese Great Inventors ([http://www.jpo.go.jp/seido\\_e/rekishi\\_e/judaie.htm](http://www.jpo.go.jp/seido_e/rekishi_e/judaie.htm)), Japanese Patent Office
- [242] **JP patent 96371** (<http://www6.ipdl.inpit.go.jp/TD/web047/20100414222036081464.gif>) – Magnetic steel added aluminum and nickel (1931-7-31)
- [243] Vita Germetika: A Brief History of Creating and Development of Soviet-Russian space suits ([http://vokrugsveta.ru/publishing/vs/archives/?item\\_id=465](http://vokrugsveta.ru/publishing/vs/archives/?item_id=465)) (**Russian**)
- [244] Cherenkov's biography ([http://nobelprize.org/nobel\\_prizes/physics/laureates/1958/cerenkov-bio.html](http://nobelprize.org/nobel_prizes/physics/laureates/1958/cerenkov-bio.html)) at Nobelprize.org
- [245] The Mechanical Advantage (<http://www.bigwalls.net/climb/mechadv/index.html>)
- [246] The origins of the pn junction ([http://ieeexplore.ieee.org/xpls/abs\\_all.jsp?arnumber=591664](http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=591664)), M. Riordan and L. Hoddeson, *IEEE Spectrum* **34**, #6 (June 1997), pp. 46–51, doi:10.1109/6.591664.
- [247] [http://wiki.answers.com/Q/Who\\_originally\\_made\\_the\\_fluorescent\\_light\\_fixture](http://wiki.answers.com/Q/Who_originally_made_the_fluorescent_light_fixture)

- [248] Gareth R. Eaton *et al.* (1998), *Foundations of modern EPR* (<http://books.google.com/?id=1LdKSYIQtPYC&pg=PA45>), World Scientific, pp. 45–46, ISBN 9810232950,
- [249] The Curious History of the First Pocket Calculator, Cliff Stoll, *Scientific American*, January 2004.
- [250] "Curta calculator", entry in *Milestones in computer science and information technology*, Edwin D. Reilly, Greenwood Publishing Group, 2003, ISBN 1-57356-521-0, p. 66.
- [251] John Brockman, editor. *The Greatest Inventions of the Past 2000 Years*. Phoenix. 2000
- [252] Monthieux, Marc; Kuznetsov, V (2006), "Who should be given the credit for the discovery of carbon nanotubes?" (<http://www.cemes.fr/fichpdf/GuestEditorial.pdf>) (PDF), *Carbon* **44**: 1621, doi:10.1016/j.carbon.2006.03.019, .
- [253] Радужкевич, Л. В. (1952), "О Структуре Углерода, Образующегося При Термическом Разложении Окиси Углерода На Железном Контакте" (<http://carbon.phys.msu.ru/publications/1952-radushkevich-lukyanovich.pdf>) (in Russian) (PDF), *Журнал Физической Химии* **26**: 88–95, .
- [254] Jack Baskin School of Engineering. (2008) *Narinder Kapany, Ph.D.*. UC Santa Cruz. ([http://www.soe.ucsc.edu/administration/dean/council/Kapany\\_Bio.html](http://www.soe.ucsc.edu/administration/dean/council/Kapany_Bio.html))
- [255] Prathap, Gangan (March 2004), "Indian science slows down: The decline of open-ended research", *Current Science* **86** (6): 768–769 [769]
- [256] "Subrata Mitra" (<http://www.cinematographers.nl/GreatDoPh/mitra.htm>). Internet Encyclopedia of Cinematographers. . Retrieved 2009-05-22.
- [257] Cardullo, Bert (November 2005), "Revisiting Satyajit Ray: An Interview with a Cinema Master" (<http://www.brightlightsfilm.com/50/rayiv.htm>), *Bright Lights Film Journal* (50), , retrieved 2009-05-24
- [258] Peter Bond, Obituary: Lt-Gen Kerim Kerimov ([http://findarticles.com/p/articles/mi\\_qn4158/is\\_20030407/ai\\_n12692130](http://findarticles.com/p/articles/mi_qn4158/is_20030407/ai_n12692130)), *The Independent*, 7 April 2003.
- [259] The thin film transistor—A late flowering bloom (<http://ieeexplore.ieee.org/search/wrapper.jsp?arnumber=1484047>), T. P. Brody, IEEE Transactions on Electron Devices, **31**, #11 (November 1984), pp. 1614–1628, at p. 1615, §II; also see An evaporated thin film triode, P. K. Weimer, presented at the IRE-AIEE Solid State Device Research Conf., Stanford University, California, 1961.
- [260] Seasolarpower.com (<http://www.seasolarpower.com>)
- [261] Sasolarpower.com (<http://www.seasolarpower.com/inventor.html>)
- [262] NASM.edu (<http://www.nasm.edu/spacecraft/SS-OSO1.htm>)
- [263] An Early Electronic Calculator, the Friden EC-130 (<http://ieeexplore.ieee.org/search/wrapper.jsp?arnumber=707577>), Bruce Flamm; in "Calculators" column, Earl Swartzlander, ed., *IEEE Annals of the History of Computing* **20**, #3 (July–September 1998), pp. 72–73.
- [264] "Electronic Quartz Wristwatch, 1969" ([http://www.ieee.org/web/aboutus/history\\_center/seiko.html](http://www.ieee.org/web/aboutus/history_center/seiko.html)). IEEE History Center. . Retrieved 2007-08-31.
- [265] Wisegeek.com (<http://www.wisegeek.com/what-is-a-charged-coupled-device.htm>)
- [266] Blair Betty (1995), "Behind Soviet Aeronauts", *Azerbaijan International* **3**: 3.
- [267] Inventing Email ([http://socrates.berkeley.edu/~scotch/innovation/inventing\\_email.pdf](http://socrates.berkeley.edu/~scotch/innovation/inventing_email.pdf))
- [268] China Daily (February 10, 2007). 4 Great Modern Inventions Selected ([http://www.chinadaily.com.cn/china/2007-02/10/content\\_806437.htm](http://www.chinadaily.com.cn/china/2007-02/10/content_806437.htm)). Chinadaily.com.cn. Retrieved on 2008-06-18.
- [269] Hybridcars.com (<http://www.hybridcars.com/hybrid-coverup-1974.html>)
- [270] Affordablephones.net (<http://affordablephones.net/HistoryCellular.htm>)
- [271] Fulford, Benjamin (24 June 2002). "Unsung hero" (<http://www.forbes.com/global/2002/0624/030.html>). Forbes. . Retrieved 2008-03-18.
- [272] US 4531203 (<http://v3.espacenet.com/textdoc?DB=EPODOC&IDX=US4531203>) Fujio Masuoka
- [273] "CDP-101 The first Compact Disc Audio CD Player from 1982" (<http://www.cedmagic.com/history/sony-cdp-101.html>). 2007. . Retrieved 2007-02-05.
- [274] p. 191, *Liquid Gold: The Story Of Liquid Crystal Displays and the Creation of an Industry*, Joseph A. Castellano, World Scientific Publishing Company, 2005, ISBN 981-238-956-3.
- [275] Stahl, Ted (July 26, 2006). "Chronology of the History of Video Games: Golden Age" ([http://www.thocp.net/software/games/golden\\_age.htm](http://www.thocp.net/software/games/golden_age.htm)). . Retrieved 2009-07-06.
- [276] p. 151, *Television: the life story of a technology*, Alexander B. Magoun, Greenwood Publishing Group, 2007, ISBN 0-313-33128-6.
- [277] B/W and color LC video displays addressed by poly Si TFT's, S. Morozumi, K. Oguchi, S. Yazawa, T. Kodaira, H. Ohshima, and T. Mano, *Proc. Society for Information Display*, Philadelphia, Pennsylvania, May 1983, pp. 156–157.
- [278] First synthesized 1989 under the name "UK-92,480". See p. 1, The discovery and development of Viagra (sildenafil citrate), Ian H. Osterloh, pp. 1–14 in *Sildenafil*, Udo Dünzendorfer, ed., Milestones in Drug Therapy ser., Birkhäuser, 2004, ISBN 3-7643-6255-3.
- [279] Proposal for the World Wide Web (<http://www.w3.org/Proposal>)
- [280] Van Buskirk, Eliot. "Introducing the world's first MP3 player" ([http://reviews.cnet.com/4520-6450\\_7-5622055-1.html](http://reviews.cnet.com/4520-6450_7-5622055-1.html)). CNET. .
- [281] Plosjournals.org (<http://biology.plosjournals.org/perlserv/?request=get-document&doi=10.1371/journal.pbio.0050266&ct=1>)
- [282] Thermo Fisher Scientific (June 3, 2008). "Dr. Alexander Makarov Receives 2008 ASMS Distinguished Contribution in Mass Spectrometry Award" ([http://www.thermo.com/com/cda/newsevents/news\\_detail/0,,20344,00.html?ca=ms](http://www.thermo.com/com/cda/newsevents/news_detail/0,,20344,00.html?ca=ms)). Press release. . Retrieved October 20, 2009.
- [283] <http://jstor.org/stable/529703>
- [284] <http://materials.iisc.ernet.in/~wootz/heritage/WOOTZ.htm>

[285] <http://www.uhpress.hawaii.edu/journals/jwh/jwh061p001.pdf>

## External links

- History of Human Technology (<http://home.entouch.net/dmd/chron.htm>)
- Encyclopædia Britannica's Great Inventions (<http://corporate.britannica.com/press/inventions.html>)
- KryssTal History and Geography of Inventions (<http://www.kryssstal.com/inventions.html>)
- U.S. National Academy of Engineering's Greatest Engineering Achievements of the 20th Century Timeline (<http://www.greatachievements.org/?id=2984>)

# Innovation

**Innovation** is the process of improving an existing product or service and not, as is commonly assumed, the introduction of something better. The term derives from the Latin *innovationem*, the noun of action from *innovare*. The Etymology Dictionary further explains *innovare* as dating back to 1540 and stemming from the Latin *innovatus*, pp. of *innovare* "to renew or change," from in- "into" + *novus* "new".

The central meaning of innovation thus relates to renewal or improvement, with novelty being a consequence of this improvement. For an improvement to take place it is necessary for people to change the way they make decisions, or make choices outside of their norm. Schumpeter c.s. (~1930) states that "innovation changes the values onto which the system is based". When people change their value system, the old (economic) system will change to make room for the better one. When that happens innovation has occurred. Innovation can be seen as something that *does* not something that *is*.

On a lower level, innovation can be seen as a change in the thought process for doing something, or the useful application of inventions or discoveries.<sup>[1]</sup> It may refer

to incremental, emergent, or radical and revolutionary changes in thinking, products, processes, or organizations. Following Schumpeter (1934), contributors to the scholarly literature on innovation typically distinguish between invention, an idea made manifest, and innovation, ideas applied successfully in practice. In many fields, such as the arts, economics and government policy, something better must be substantially different to be innovative. In economics the change must increase value, customer value, or producer value. The goal of invention is positive change, to make someone or something better. Invention and introduction of it that leads to increased productivity is the fundamental source of increasing wealth in an economy.

Innovation is an important topic in the study of economics, business, entrepreneurship, design, technology, sociology, and engineering. Colloquially, the word "innovation" is often synonymous with the output of the process. However, economists tend to focus on the process itself, from the origination of an idea to its transformation into



A confusing personification of the innovator as represented by a statue in The American Adventure in the World Showcase pavilion of Walt Disney World's Epcot. Effectively an inventor is displayed.

something useful, to its implementation; and on the system within which the process of innovation unfolds. Since innovation is also considered a major driver of the economy, especially when it leads to new product categories or increasing productivity, the factors that lead to innovation are also considered to be critical to policy makers. In particular, followers of innovation economics stress using public policy to spur innovation and growth.

Those who are directly responsible for application of inventions are often called pioneers in their field, whether they are individuals or organizations. When pioneers are followed by many others, the dominant value system may be replaced by the better one. When this happens innovation has occurred *a posteriori*:

The spark that set off the explosive boom of "Silicon startups" in Stanford Industrial Park was a personal dispute in 1957 between employees of Shockley Semiconductor and the company's namesake and founder, Nobel laureate and co-inventor of the transistor William Shockley... (His employees) formed Fairchild Semiconductor immediately following their departure...

After several years, Fairchild gained its footing, becoming a formidable presence in this sector. Its founders began to leave to start companies based on their own, latest ideas and were followed on this path by their own former leading employees... The process gained momentum and what had once began in a Stanford's research park became a veritable startup avalanche... Thus, over the course of just 20 years, a mere eight of Shockley's former employees gave forth 65 new enterprises, which then went on to do the same...<sup>[2]</sup>

## Introduction

In the organizational context, innovation may be linked to positive changes in efficiency, productivity, quality, competitive positioning, market share, etc. can all be affected positively by innovative forces. All organizations can innovate, including for example hospitals, universities, and local governments. Some will flourish under its influence. Other will die.

So as innovation typically changes value, innovation may also have a negative or destructive effect as new developments clear away or change old organizational forms and practices. Organizations that do not compensate effectively for innovative forces (mainly from outside) may be destroyed by those that do. Hence managing an organization typically involves risk. A key challenge in management is maintaining a balance between the current processes and business model.

Innovation has been studied in a variety of contexts, including in relation to technology, commerce, social systems, economic development, and policy construction. There are, therefore, naturally a wide range of approaches to conceptualizing innovation in the scholarly literature.<sup>[3]</sup>

## Distinguishing from invention

Invention is the embodiment of something better and, as a consequence, new. While both invention and innovation have "uniqueness" implications, innovation is related to acceptance in society, profitability and market performance expectation.

An improvement on an existing form or embodiment, composition or processes might be an invention, an innovation, both or neither if it is not substantial enough. According to certain business literature, an idea, a change or an improvement is only an innovation when it is put to use, is accepted by users and effectively causes a social or commercial reorganization.

In business, innovation can be easily distinguished from invention. Invention is the conversion of cash into ideas. Innovation is the conversion of ideas into cash. This is best described by comparing Thomas Edison with Nikola Tesla. Thomas Edison was an innovator because he made money from his ideas. Nikola Tesla was an inventor. Tesla spent money to create his inventions but was unable to monetize them. Innovators produce, market and profit from their innovations. Inventors may or may not profit from their work.

## In organizations

Expert Cris Beswick <sup>[4]</sup> (2010) defines innovation as: "*The successful exploitation of an idea that adds value to the customer and commercial return for the creator*"<sup>[5]</sup>

A convenient definition of innovation from an organizational perspective is given by Luecke and Katz (2003), who wrote:

*"Innovation . . . is generally understood as the successful introduction of a better thing or method . . . Innovation is the embodiment, combination, or synthesis of knowledge in original, relevant, valued new products, processes, or services."*

A content analysis on the term "innovation" carried out by Baregheh et al. (2009) within the organizational context, defines innovation as:

*"Innovation is the multi-stage process whereby organizations transform ideas into improved products, service or processes, in order to advance, compete and differentiate themselves successfully in their marketplace."*<sup>[6]</sup>

Innovation typically involves creativity, but is not identical to it: innovation involves acting on the creative ideas to make some specific and tangible difference in the domain in which the innovation occurs. For example, Amabile et al. (1996) (Amabile, T. M., R. Conti, et al. (1996). "Assessing the work environment for creativity." *Academy of Management Journal* 39(5): 1154-1184) propose:

*"All innovation begins with creative ideas . . . We define innovation as the successful implementation of creative ideas within an organization. In this view, creativity by individuals and teams is a starting point for innovation; the first is necessary but not sufficient condition for the second".*

For innovation to occur, something more than the generation of a creative idea or insight is required: the insight must be put into action to make a genuine difference, resulting for example in better or altered business processes within the organization, or positive changes in the products and services provided.

*"Innovation, like many business functions, is a management process that requires specific tools, rules, and discipline."*

From this point of view emphasis is moved from the introduction of specific useful ideas to the general organizational processes and procedures for generating, considering, and acting on such insights leading to significant organizational improvements in terms of improved or new business products, services, or internal processes.

Through these varieties of viewpoints, creativity is typically seen as the basis for innovation, and innovation as the successful implementation of creative ideas within an organization.

It should be noted, however, that the term 'innovation' is used by many authors rather interchangeably with the term 'creativity' when discussing individual and organizational creative activity.

## Economic conceptions

Joseph Schumpeter defined economic innovation in "Theorie der Wirtschaftlichen Entwicklung" (1912). (The Theory of Economic Development, 1934, Harvard University Press, Boston.)<sup>[7]</sup>

1. The introduction of a new good — that is one with which consumers are not yet familiar — or of a new quality of a good.
2. The introduction of a improved or better method of production, which need by no means be founded upon a discovery scientifically new, and can also exist in a better way of handling a commodity commercially.
3. The opening of a new market, that is a market into which the particular branch of manufacture of the country in question has not previously entered, whether or not this market has existed before.
4. The conquest of a new source of supply of raw materials or half-manufactured goods, again irrespective of whether this source already exists or whether it has first to be created.



5. The carrying out of the better organization of any industry, like the creation of a monopoly position (for example through trustification) or the breaking up of a monopoly position

Schumpeter's focus on innovation is reflected in Neo-Schumpeterian economics, developed by such scholars as Christopher Freeman<sup>[8]</sup> and Giovanni Dosi.<sup>[9]</sup>

Innovation is also studied by economists in a variety of other contexts, for example in theories of entrepreneurship or in Paul Romer's New Growth Theory. In network theory, innovation can be seen as "an element introduced in the network which positive changes, even if momentarily, the costs of transactions between at least two actors, elements or nodes, in the network".<sup>[10]</sup>

## Market outcome

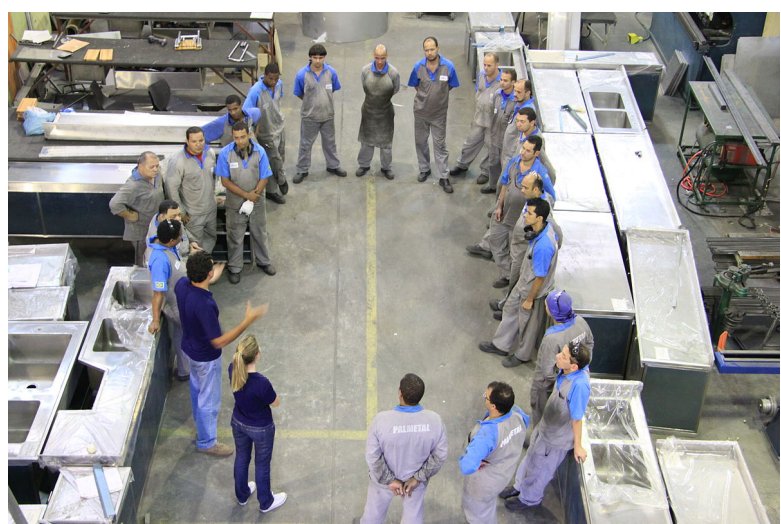
Market outcome from innovation can be studied from different lenses. The industrial organizational approach of market characterization according to the degree of competitive pressure and the consequent modelling of firm behavior often using sophisticated game theoretic tools, while permitting mathematical modelling, has shifted the ground away from the usual understanding of markets. The earlier visual framework in economics, of market demand and supply along price and quantity dimensions, has given way to powerful mathematical models which though intellectually satisfying has led policy makers and managers groping for more intuitive and less theoretical analyses to which they can relate to at a practical level.

In the management (strategy) From an academic point of view, there is often a divorce between industrial organisation theory and strategic management models. While many economists view management models as being too simplistic, strategic management consultants perceive academic economists as being too theoretical, and the analytical tools that they devise as too complex for managers to understand.

Innovation literature while rich in typologies and descriptions of innovation dynamics is mostly technology focused. Most research on innovation has been devoted to the process (technological) of innovation, or has otherwise taken a how to (innovate) approach.

## Sources of innovation

There are several sources of innovation. In the linear model of innovation the traditionally recognized source is *manufacturer innovation*. This is where an agent (person or business) innovates in order to sell the innovation. Another source of innovation, only now becoming widely recognized, is *end-user innovation*. This is where an agent (person or company) develops an innovation for their own (personal or in-house) use because existing products do not meet their needs. Eric von Hippel has identified end-user innovation as, by far, the most important and critical in his classic book on the subject, *Sources of Innovation*.<sup>[11]</sup>



**Training meeting** about sustainable design. The photo shows a training meeting with factory workers in a stainless steel ecodeign company from Rio de Janeiro, Brazil. The work force is a very important source of innovation

Joseph F. Engelberger, paraphrasing the conclusion of the 1967 US DoD program "Project Hindsight", says that innovations require only three things:<sup>[12]</sup> 1. A recognized need, 2. Competent people with relevant technology, and 3. Financial support.

Innovation by businesses is achieved in many ways, with much attention now given to formal research and development for "breakthrough innovations." But innovations may be developed by less formal on-the-job modifications of practice, through exchange and combination of professional experience and by many other routes. The more radical and revolutionary innovations tend to emerge from R&D, while more incremental innovations may emerge from practice – but there are many exceptions to each of these trends. accelerated radical innovation is another buzzword topping radical innovation expressing the target to move things quicker than by relying on the ideas flowing in from inventors. User as customers buying products or using services are an important factor in innovation. Firms may incorporate users in focus groups (user centred approach), work closely with so called lead users (lead user approach) or users might adapt their products them selves.<sup>[13]</sup> Regarding this user innovation, a great deal of innovation is done by those actually implementing and using technologies and products as part of their normal activities. In most of the times user innovators have some personal record motivating them. Sometimes user-innovators may become entrepreneurs, selling their product, they may choose to trade their innovation in exchange for other innovations, or they may be adopted by their suppliers. Nowadays, they may also choose to freely reveal their innovations, using methods like open source. In such networks of innovation the users or communities of users can further develop technologies and reinvent their social meaning.<sup>[14]</sup>

Whether innovation is mainly supply-pushed (based on new technological possibilities) or demand-led (based on social needs and market requirements) has been a hotly debated topic. Similarly, what exactly drives innovation in organizations and economies remains an open question.

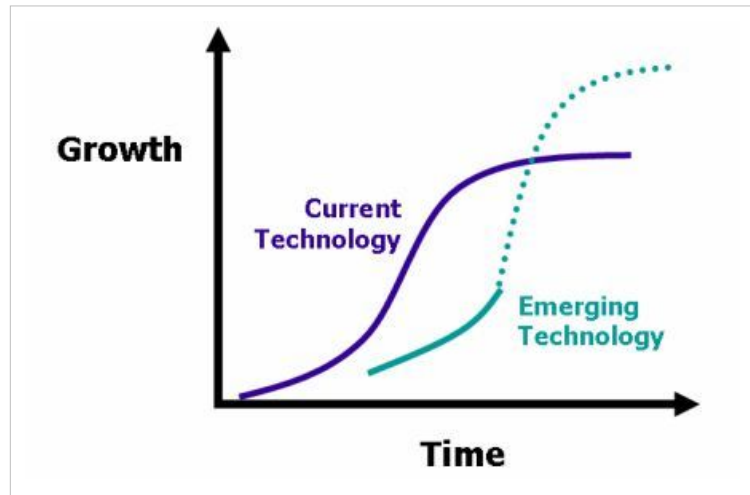
More recent theoretical work moves beyond this simple dualistic problem, and through empirical work shows that innovation does not just happen within the industrial supply-side, or as a result of the articulation of user demand, but through a complex set of processes that links many different players together – not only developers and users, but a wide variety of intermediary organisations such as consultancies, standards bodies etc. Work on social networks suggests that much of the most successful innovation occurs at the boundaries of organisations and industries where the problems and needs of users, and the potential of technologies can be linked together in a creative process that challenges both.

## **Value of experimentation**

When an innovative idea requires a new business model, or radically redesigns the delivery of value to focus on the customer, a real world experimentation approach increases the chances of market success. New business models and customer experiences can't be tested through traditional market research methods. Pilot programs for new innovations set the path in stone too early thus increasing the costs of failure. On the other hand, the good news is that recent years have seen considerable progress in identifying important key factors/principles or variables that affect the probability of success in innovation. Of course, building successful businesses is such a complicated process, involving subtle interdependencies among so many variables in dynamic systems, that it is unlikely to ever be made perfectly predictable. But the more business can master the variables and experiment, the more they will be able to create new companies, products, processes and services that achieve what they hope to achieve.<sup>[15]</sup> <sup>[16]</sup>

## Diffusion

Once innovation occurs, innovations may be spread from the innovator to other individuals and groups. This process has been proposed that the life cycle of innovations can be described using the 's-curve' or diffusion curve. The s-curve maps growth of revenue or productivity against time. In the early stage of a particular innovation, growth is relatively slow as the new product establishes itself. At some point customers begin to demand and the product growth increases more rapidly. New incremental innovations or



changes to the product allow growth to continue. Towards the end of its life cycle growth slows and may even begin to decline. In the later stages, no amount of new investment in that product will yield a normal rate of return.

The s-curve derives from an assumption that new products are likely to have "product Life". i.e. a start-up phase, a rapid increase in revenue and eventual decline. In fact the great majority of innovations never get off the bottom of the curve, and never produce normal returns.

Innovative companies will typically be working on new innovations that will eventually replace older ones. Successive s-curves will come along to replace older ones and continue to drive growth upwards. In the figure above the first curve shows a current technology. The second shows an emerging technology that current yields lower growth but will eventually overtake current technology and lead to even greater levels of growth. The length of life will depend on many factors.

## Goals

Programs of organizational innovation are typically tightly linked to organizational goals and objectives, to the business plan, and to market competitive positioning. One driver for innovation programs in corporations is to achieve growth objectives. As Davila et al. (2006) note,

"Companies cannot grow through cost reduction and reengineering alone... Innovation is the key element in providing aggressive top-line growth, and for increasing bottom-line results" (p.6)

In general, business organisations spend a significant amount of their turnover on innovation, such as making changes to their established products, processes and services. The amount of investment can vary from as low as a half a percent of turnover for organisations with a low rate of change to anything over twenty percent of turnover for organisations with a high rate of change.

The average investment across all types of organizations is four percent. For an organisation with a turnover of one billion currency units, this would represent an investment of forty million units. This budget will typically be spread across various functions including marketing, product design, information systems, manufacturing systems and quality assurance. The investment may vary by industry and by market positioning.

One survey across a large number of manufacturing and services organisations found, ranked in decreasing order of popularity, that systematic programs of organizational innovation are most frequently driven by:

1. Improved quality
2. Creation of new markets
3. Extension of the product range

4. Reduced labour costs
5. Improved production processes
6. Reduced materials
7. Reduced environmental damage
8. Replacement of products/services
9. Reduced energy consumption
10. Conformance to regulations

These goals vary between improvements to products, processes and services and dispel a popular myth that innovation deals mainly with new product development. Most of the goals could apply to any organisation be it a manufacturing facility, marketing firm, hospital or local government. Whether innovation goals are successfully achieved or otherwise depends greatly on the environment prevailing in the firm.<sup>[17]</sup>

## Failure

Research findings vary, ranging from fifty to ninety percent of innovation projects judged to have made little or no contribution to organizational goals. One survey regarding product innovation quotes that out of three thousand ideas for new products, only one becomes a success in the marketplace. Failure is an inevitable part of the innovation process, and most successful organisations factor in an appropriate level of risk. Perhaps it is because all organisations experience failure that many choose not to monitor the level of failure very closely. The impact of failure goes beyond the simple loss of investment. Failure can also lead to loss of morale among employees, an increase in cynicism and even higher resistance to change in the future.

Innovations that fail are often potentially good ideas but have been rejected or postponed due to budgetary constraints, lack of skills or poor fit with current goals. Failures should be identified and screened out as early in the process as possible. Early screening avoids unsuitable ideas devouring scarce resources that are needed to progress more beneficial ones. Organizations can learn how to avoid failure when it is openly discussed and debated. The lessons learned from failure often reside longer in the organisational consciousness than lessons learned from success. While learning is important, high failure rates throughout the innovation process are wasteful and a threat to the organisation's future.

The causes of failure have been widely researched and can vary considerably. Some causes will be external to the organisation and outside its influence of control. Others will be internal and ultimately within the control of the organisation. Internal causes of failure can be divided into causes associated with the cultural infrastructure and causes associated with the innovation process itself. Failure in the cultural infrastructure varies between organizations but the following are common across all organisations at some stage in their life cycle (O'Sullivan, 2002):

1. Poor Leadership
2. Poor Organization
3. Poor Communication
4. Poor Empowerment
5. Poor Knowledge Management

Common causes of failure within the innovation process in most organisations can be distilled into five types:

1. Poor goal definition
  2. Poor alignment of actions to goals
  3. Poor participation in teams
  4. Poor monitoring of results
  5. Poor communication and access to information
-

Effective goal definition requires that organisations state explicitly what their goals are in terms understandable to everyone involved in the innovation process. This often involves stating goals in a number of ways. Effective alignment of actions to goals should link explicit actions such as ideas and projects to specific goals. It also implies effective management of action portfolios. Participation in teams refers to the behaviour of individuals in and of teams, and each individual should have an explicitly allocated responsibility regarding their role in goals and actions and the payment and rewards systems that link them to goal attainment. Finally, effective monitoring of results requires the monitoring of all goals, actions and teams involved in the innovation process.

Innovation can fail if seen as an organisational process whose success stems from a mechanistic approach i.e. 'pull lever obtain result'. While 'driving' change has an emphasis on control, enforcement and structure it is only a partial truth in achieving innovation. Organisational gatekeepers frame the organisational environment that "Enables" innovation; however innovation is "Enacted" – recognised, developed, applied and adopted – through individuals.

Individuals are the 'atom' of the organisation close to the minutiae of daily activities. Within individuals gritty appreciation of the small detail combines with a sense of desired organisational objectives to deliver (and innovate for) a product/service offer.

From this perspective innovation succeeds from strategic structures that engage the individual to the organisation's benefit. Innovation pivots on intrinsically motivated individuals, within a supportive culture, informed by a broad sense of the future.

Innovation, implies change, and can be counter to an organisation's orthodoxy. Space for fair hearing of innovative ideas is required to balance the potential autoimmune exclusion that quells an infant innovative culture.

## Measures

There are two fundamentally different types of measures for innovation: the organizational level and the political level. The measure of innovation at the organizational level relates to individuals, team-level assessments, private companies from the smallest to the largest. Measure of innovation for organizations can be conducted by surveys, workshops, consultants or internal benchmarking. There is today no established general way to measure organizational innovation. Corporate measurements are generally structured around balanced scorecards which cover several aspects of innovation such as business measures related to finances, innovation process efficiency, employees' contribution and motivation, as well benefits for customers. Measured values will vary widely between businesses, covering for example new product revenue, spending in R&D, time to market, customer and employee perception & satisfaction, number of patents, additional sales resulting from past innovations.

For the political level, measures of innovation are more focussing on a country or region competitive advantage through innovation. In this context, organizational capabilities can be evaluated through various evaluation frameworks, such as those of the European Foundation for Quality Management. The OECD Oslo Manual (1995) suggests standard guidelines on measuring technological product and process innovation. Some people consider the Oslo Manual complementary to the Frascati Manual from 1963. The new Oslo manual from 2005 takes a wider perspective to innovation, and includes marketing and organizational innovation. These standards are used for example in the European Community Innovation Surveys.

Other ways of measuring innovation have traditionally been expenditure, for example, investment in R&D (Research and Development) as percentage of GNP (Gross National Product). Whether this is a good measurement of Innovation has been widely discussed and the Oslo Manual has incorporated some of the critique against earlier methods of measuring. The traditional methods of measuring still inform many policy decisions. The EU Lisbon Strategy has set as a goal that their average expenditure on R&D should be 3% of GNP.

Several indexes exist that attempt to measure innovation within the U.S.

- The Innovation Index <sup>[18]</sup>, developed by the Indiana Business Research Center, to measure innovation capacity at the county or regional level

- The State Technology and Science Index <sup>[19]</sup> from the Milken Institute

The Oslo Manual is focused on North America, Europe, and other rich economies. In 2001 for Latin America and the Caribbean countries it was created the Bogota Manual

Many scholars claim that there is a great bias towards the "science and technology mode" (S&T-mode or STI-mode), while the "learning by doing, using and interacting mode" (DUI-mode) is widely ignored. For an example, that means you can have the better high tech or software, but there are also crucial learning tasks important for innovation. But these measurements and research are rarely done.

A common industry view (unsupported by empirical evidence) is that comparative cost-effectiveness research (CER) is a form of price control which, by reducing returns to industry, limits R&D expenditure, stifles future innovation and compromises new products access to markets.<sup>[20]</sup> Some academics claim the CER is a valuable value-based measure of innovation which accords truly significant advances in therapy (those that provide 'health gain') higher prices than free market mechanisms.<sup>[21]</sup> Such value-based pricing has been viewed as a means of indicating to industry the type of innovation that should be rewarded from the public purse.<sup>[22]</sup> The Australian academic Thomas Alured Faunce has developed the case that national comparative cost-effectiveness assessment systems should be viewed as measuring 'health innovation' as an evidence-based concept distinct from valuing innovation through the operation of competitive markets (a method which requires strong anti-trust laws to be effective) on the basis that both methods of assessing innovation in pharmaceuticals are mentioned in annex 2C.1 of the AUSFTA.<sup>[23] [24] [25]</sup>

### Political Level Studies

There are several international benchmarking studies of the innovation performance of countries (above called the political level), Global Innovation Index (below) being one. Other examples are Richard Florida's index for the **Creative Class** and the **Innovation Capacity Index (ICI)**<sup>[26]</sup> published by a large number of international professors working in a collaborative fashion. The top scorers of ICI 2009-2010 being: #1. Sweden 82.2, #2. Finland 77.8, and #3. United States 77.5.

The **Global Innovation Index** is a global index measuring the level of innovation of a country, produced jointly by The Boston Consulting Group (BCG), the National Association of Manufacturers (NAM), and The Manufacturing Institute (MI), the NAM's nonpartisan research affiliate. NAM describes it as the "largest and most comprehensive global index of its kind".<sup>[27]</sup>

The International Innovation Index is part of a large research study that looked at both the business outcomes of innovation and government's ability to encourage and support innovation through public policy. The study comprised a survey of more than 1,000 senior executives from NAM member companies across all industries; in-depth interviews with 30 of the executives; and a comparison of the "innovation friendliness" of 110 countries and all 50 U.S. states. The findings are published in the report, "The Innovation Imperative in Manufacturing: How the United States Can Restore Its Edge."<sup>[28]</sup>

The report discusses not only country performance but also what companies are doing and should be doing to spur innovation. It looks at new policy indicators for innovation, including tax incentives and policies for immigration, education and intellectual property.

The latest index was published in March 2009.<sup>[29]</sup> To rank the countries, the study measured both innovation inputs and outputs. Innovation inputs included government and fiscal policy, education policy and the innovation environment. Outputs included patents, technology transfer, and other R&D results; business performance, such as labor productivity and total shareholder returns; and the impact of innovation on business migration and economic growth. The following is a list of the twenty largest countries (as measured by GDP) by the International Innovation Index:

Rank	Country	Overall	Innovation Inputs	Innovation Performance
1	 South Korea	2.26	1.75	2.55
2	 United States	1.80	1.28	2.16
3	 Japan	1.79	1.16	2.25
4	 Sweden	1.64	1.25	1.88
5	 Netherlands	1.55	1.40	1.55
6	 Canada	1.42	1.39	1.32
7	 United Kingdom	1.42	1.33	1.37
8	 Germany	1.12	1.05	1.09
9	 France	1.12	1.17	0.96
10	 Australia	1.02	0.89	1.05
11	 Spain	0.93	0.83	0.95
12	 Belgium	0.86	0.85	0.79
13	 China	0.73	0.07	1.32
14	 Italy	0.21	0.16	0.24
15	 India	0.06	0.14	-0.02
16	 Russia	-0.09	-0.02	-0.16
17	 Mexico	-0.16	0.11	-0.42
18	 Turkey	-0.21	0.15	-0.55
19	 Indonesia	-0.57	-0.63	-0.46
20	 Brazil	-0.59	-0.62	-0.51

## Public awareness

Public awareness of innovation is an important part of the innovation process. This is further discussed in the emerging fields of innovation journalism and innovation communication.

## Government policies encouraging innovation

Many governments have crafted policies to promote innovation in the economy. These include increased government spending on R&D and education. An example of an innovation programme is the Medvedev modernisation programme in Russia which aims at creating a diversified economy based on high technology and innovation.

## References

- Barras, R. (1984). "Towards a theory of innovation in services". *Research Policy* **15**: 161–73. doi:10.1016/0048-7333(86)90012-0.
- Byrd, Jacqueline (2003). *The Innovation Equation – Building Creativity & Risk Taking in your Organization*. San Francisco, CA: Jossey-Bass/Pfeiffer – Aprint. ISBN 0-7879-6250-3.
- Cabral, Regis (1998). "Refining the Cabral-Dahab Science Park Management Paradigm". *Int. J. Technology Management* **16** (8): 813–818. doi:10.1504/IJTM.1998.002694..
- Cabral, Regis (2003). "Development, Science and". In Heilbron, J.. *The Oxford Companion to The History of Modern Science* <sup>[30]</sup>. New York: Oxford University Press. pp. 205–207.
- Chakravorti, Bhaskar (2003). *The Slow Pace of Fast Change: Bringing Innovations to Market in a Connected World*. Boston, MA: Harvard Business School Press.
- Chesbrough, Henry William (2003). *Open Innovation: The New Imperative for Creating and Profiting from Technology*. Boston, MA: Harvard Business School Press.. ISBN 1-57851-837-7.
- Christensen, Clayton M. (1997). *The Innovator's Dilemma*. Boston, MA: Harvard Business School Press. ISBN 0-06-052199-6.
- Christensen, Clayton M. (2002). "The Rules of Innovation". *Technology Review* **105** (5): 32–38.
- Davila, Tony; Marc J. Epstein and Robert Shelton (2006). *Making Innovation Work: How to Manage It, Measure It, and Profit from It*. Upper Saddle River: Wharton School Publishing. ISBN 0-13-149786-3.
- Mckeown, Max (2008). *The Truth About Innovation*. London: Prentice Hall. ISBN 978-0273719120.
- Dosi, Giovanni (1982). "Technological paradigms and technological trajectories". *Research Policy* **11** (3): 147–162.
- Ettlie, John E. (2006). *Managing Innovation* (2nd ed.). Butterworth-Heinemann, an imprint of Elsevier. ISBN 0-7506-7895-X.
- Evangelista, Rinaldo (2000). "Sectoral patterns of technological change in services, economics of innovation". *Economics of Innovation and New Technology* **9**: 183–221. doi:10.1080/10438590000000008.
- Fagerberg, Jan (2004). "Innovation: A Guide to the Literature". In Fagerberg, Jan, David C. Mowery and Richard R. Nelson. *The Oxford Handbook of Innovations*. Oxford University Press. pp. 1–26. ISBN 0-19-926455-4.
- Freeman, Chris (1984). "Prometheus Unbound". *Futures* **16** (5): 494–507.. doi:10.1016/0016-3287(84)90080-6.
- Freeman, Chris (1982). *The Economics of Industrial Innovation*. Frances Pinter, London.
- Hesselbein, Frances, Marshall Goldsmith, and Iain Sommerville, ed (2002). *Leading for Innovation: And organizing for results*. Jossey-Bass. ISBN 0-7879-5359-8.
- Hitcher, Waldo (2006). *Innovation Paradigm Replaced*. Wiley.
- Luecke, Richard; Ralph Katz (2003). *Managing Creativity and Innovation*. Boston, MA: Harvard Business School Press. ISBN 1-59139-112-1.
- Mansfield, Edwin (1985). "How Rapidly Does New Industrial Technology Leak Out?" <sup>[31]</sup>. *Journal of Industrial Economics* (The Journal of Industrial Economics, Vol. 34, No. 2) **34** (2): 217–223.. doi:10.2307/2098683.
- Miles, Ian (2000). "Services Innovation: Coming of Age in the Knowledge Based Economy". *International Journal of Innovation Management* **14** (4): 371–389.. doi:10.1016/S1363-9196(00)00020-2.
- Miles, Ian (2004). "Innovation in Services". In Fagerberg, Jan, David C. Mowery and Richard R. Nelson. *The Oxford Handbook of Innovations*. Oxford University Press. pp. 433–458. ISBN 0-19-926455-4.
- Nelson, Richard; Winter, S (1977). "In search of a useful theory of Innovation". *Research Policy* **6** (1): 36–76. doi:10.1016/0048-7333(77)90029-4.
- OECD *The Measurement of Scientific and Technological Activities. Proposed Guidelines for Collecting and Interpreting Technological Innovation Data. Oslo Manual*. 2nd edition, DSTI, OECD / European Commission Eurostat, Paris 31 Dec 1995.
- O'Sullivan, David (2002). "Framework for Managing Development in the Networked Organisations". *Journal of Computers in Industry* (Elsevier Science Publishers B. V.) **47** (1): 77–88. doi:10.1016/S0166-3615(01)00135-X.



ISSN 0166–3615.

- Rogers, Everett M. (1962). *Diffusion of Innovation*. New York, NY: Free Press.
- Rosenberg, Nathan (1975). *Perspectives on Technology*. Cambridge, London and N.Y.: Cambridge University Press.
- Sarkar, Soumodip (2007). *Innovation, Market Archetypes and Outcome- An Integrated Framework*. Springer Verlag. ISBN 379081945X.
- Schumpeter, Joseph (1934). *The Theory of Economic Development*. Cambridge, MA: Harvard University Press.
- Scotchmer, Suzanne (2004). *Innovation and Incentives*. Cambridge, MA: MIT Press.
- Silvestre, Bruno dos Santos; Dalcol, Paulo Roberto Tavares. "Geographical proximity and innovation: Evidences from the Campos Basin oil & gas industrial agglomeration—Brazil". *Technovation* (Elsevier) **29** (8): 546–561. doi:10.1016/j.technovation.2009.01.003. ISSN 0166-4972.
- Stein, Morris (1974). *Stimulating creativity*. New York: Academic Press.
- Utterback, James M.; Fernando F. Suarez. (1993). "Innovation, Competition, and Industry Structure". *Research Policy* **22** (1): 1–21. doi:10.1016/0048-7333(93)90030-L.
- Veneris, Yannis (1984). *The Informational Revolution, Cybernetics and Urban Modelling, PhD Thesis*. University of Newcastle upon Tyne, UK.
- Veneris, Yannis (1990). "Modeling the transition from the Industrial to the Informational Revolution". *Environment and Planning A* **22** (3): 399–416. doi:10.1068/a220399.
- von Hippel, Eric (2005). *Democratizing Innovation*. MIT Press. ISBN 0-262-22074-1.
- Woodman, Richard W.; John E. Sawyer, Ricky W. Griffin (1993). "Toward a theory of organizational creativity"<sup>[32]</sup>. *Academy of Management Review* (*The Academy of Management Review*, Vol. 18, No. 2) **18** (2): 293–321. doi:10.2307/258761.
- Wolpert, John (2002). "Breaking Out of the Innovation Box". *Harvard Business Review* **August**.

## Online references

- [1] McKeown, Max (2008). *The Truth About Innovation*. London, UK: Prentice Hall. ISBN 0273719122.
- [2] A Legal Bridge Spanning 100 Years: From the Gold Mines of El Dorado to the 'Golden' Startups of Silicon Valley ([http://www.netvalley.com/silicon\\_valley/Legal\\_Bridge\\_From\\_El\\_Dorado\\_to\\_Silicon\\_Valley.html](http://www.netvalley.com/silicon_valley/Legal_Bridge_From_El_Dorado_to_Silicon_Valley.html)) by Gregory Gromov 2010.
- [3] Fagerberg et al. (2004).
- [4] <http://www.letsthinkbeyond.com>
- [5] Beswick, C; Gallagher, D (2010) *The Road to Innovation*. LTBpublishing. UK. pp10.
- [6] Baregheh A, Rowley J and Sambrook S.(2009) Towards a multidisciplinary definition of innovation, *Management decision*, vol. 47, no. 8, pp. 1323–1339
- [7] Schumpeter, Joseph (1934). *The Theory of Economic Development*. Harvard University Press, Boston.
- [8] Freeman, Christopher (1982). *The Economics of Industrial Innovation*. Frances Pinter, London..
- [9] Dosi, Giovanni (1982). "Technological paradigms and technological trajectories". *Research Policy* **11** (3): 147–162.
- [10] Regis Cabral (1998, 2003)
- [11] von Hippel, Eric (1988). *The Sources of Innovation* (<http://web.mit.edu/evhippel/www/books/sources/SofI.pdf>). Oxford University Press. ISBN 0–19–509422–0.
- [12] "Robotics in practice: Future capabilities" by Joseph F. Engelberger.: in "Electronic Servicing & Technology" magazine 1982 August
- [13] <http://www.u-stir.eu>
- [14] Tuomi, Ilkka (2002). *Networks of Innovation* (<http://www.oup.com/uk/catalogue/?ci=9780199256983>). Oxford University Press. ISBN 978-0-19-925698-3.
- [15] Christensen, Clayton (2002). "The Rules of Innovation". *Technology Review* **105** (5): 32–38.
- [16] Thomke, Stefan H. (2003) *Experimentation Matters: Unlocking the Potential of New Technologies for Innovation*. Harvard Business School Press. ISBN 1578517508. ([http://books.google.com/books?id=nM-5IWBGhoEC&pg=PA163&dq=Anticipate+and+Exploit+Early+Information+Through+Front-Loaded+Innovation+Processes&sig=F6hTlIVtx3j3kkX\\_tOoWBF8Br5Q#PPA163.M1](http://books.google.com/books?id=nM-5IWBGhoEC&pg=PA163&dq=Anticipate+and+Exploit+Early+Information+Through+Front-Loaded+Innovation+Processes&sig=F6hTlIVtx3j3kkX_tOoWBF8Br5Q#PPA163.M1))
- [17] Khan, Arshad M.; V. Manopichetwattana (1989). "Innovative and Noninnovative Small Firms: Types and Characteristics". *Management Science* **35** (5): 597–606.. doi:10.1287/mnsc.35.5.597.
- [18] <http://www.statsamerica.org/innovation/data.html>
- [19] <http://www.milkeninstitute.org/tech/>

- [20] Chalkidou K, Tunis S, Lopert R, Rochaix L, Sawicki PT, Nasser M, Xerri B. Comparative Effectiveness research and Evidence-Based Health Policy: Experience from Four Countries. *The Milbank Quarterly* 2009; 87(2): 339-367 at 362-363.
- [21] Roughead E, Lopert R and Sansom L. Prices for innovative pharmaceutical products that provide health gain: a comparison between Australia and the United States *Value in Health* 2007;10:514-20
- [22] Hughes B. Payers Growing Influence on R&D Decision Making. *Nature Reviews Drugs Discovery* 2008; 7: 876-78.
- [23] Faunce T, Bai J and Nguyen D. Impact of the Australia-US Free Trade Agreement on Australian medicines regulation and prices. *Journal of Generic Medicines* 2010; 7(1): 18-29
- [24] Faunce TA. Global intellectual property protection of "innovative" pharmaceuticals:Challenges for bioethics and health law in B Bennett and G Tomossy (eds) *Globalization and Health* Springer 2006 <http://law.anu.edu.au/StaffUploads/236-Ch%20Globalisation%20and%20Health%20Fau.pdf> . Retrieved 18 June 2009.
- [25] Faunce TA. Reference pricing for pharmaceuticals: is the Australia-United States Free Trade Agreement affecting Australia's Pharmaceutical Benefits Scheme? *Medical Journal of Australia*. 2007 Aug 20;187(4):240-2.
- [26] <http://www.innovationfordevelopmentreport.org/>
- [27] "America Ranks #8 In New Global Innovation Index" (<http://www.nam.org/NewsFromtheNAM.aspx?DID={8D10F9A6-28AE-456D-97EA-340146144190}>). Nam.org. . Retrieved 2009-08-28.
- [28] "U.S. Ranks #8 In Global Innovation Index" ([http://www.industryweek.com/articles/u-s\\_ranks\\_8\\_in\\_global\\_innovation\\_index\\_18638.aspx](http://www.industryweek.com/articles/u-s_ranks_8_in_global_innovation_index_18638.aspx)). Industryweek.com. 2009-03-10. . Retrieved 2009-08-28.
- [29] "The Innovation Imperative in Manufacturing: How the United States Can Restore Its Edge" (<http://www.nam.org/innovationreport.pdf>) (PDF). . Retrieved 2009-08-28.
- [30] [http://www.oxfordreference.com/pages/Subjects\\_and\\_titles\\_\\_t132.html](http://www.oxfordreference.com/pages/Subjects_and_titles__t132.html)
- [31] <http://jstor.org/stable/2098683>
- [32] <http://jstor.org/stable/258761>

## External links

- Academic article on Being a Systems Innovator ([http://papers.ssrn.com/sol3/papers.cfm?abstract\\_id=964672](http://papers.ssrn.com/sol3/papers.cfm?abstract_id=964672)) on SSRN
- "Communication on Innovation policy: updating the Union's approach in the context of the Lisbon strategy" (<http://ec.europa.eu/enterprise/innovation/communication.htm>) – The European Commission.
- Commission proposes 2009 to become European Year of Creativity and Innovation (<http://europa.eu/rapid/pressReleasesAction.do?reference=IP/08/482&format=HTML&aged=0&language=EN&guiLanguage=en>) – The European Commission.
- PRO-INNO Europe - Innovation policy analysis and development throughout Europe (<http://www.proinno-europe.eu>) (Initiative of the European Commission).
- 12 Innovations that Changed the World (<http://www.saturdayeveningpost.com/2009/08/24/lifestyle/features/12-innovations-changed-world.html>)

# Patent

Intellectual property law
Primary rights
<b>Copyright</b> • Authors' rights Related rights • Moral rights <b>Patent</b> • Utility model <b>Trademark</b> Geographical indication <b>Trade secret</b>
Sui generis rights
Database right Indigenous intellectual property Industrial design right Mask work • Plant breeders' rights Supplementary protection certificate
Related topics
Criticism • Orphan works Public domain • more

A **patent** (pronounced /'pætənt/ or English pronunciation: /'peɪtənt/) is a set of exclusive rights granted by a state (national government) to an inventor or their assignee for a limited period of time in exchange for a public disclosure of an invention.

The procedure for granting patents, the requirements placed on the patentee, and the extent of the exclusive rights vary widely between countries according to national laws and international agreements. Typically, however, a patent application must include one or more claims defining the invention which must be new, non-obvious, and useful or industrially applicable. In many countries, certain subject areas are excluded from patents, such as business methods and mental acts. The exclusive right granted to a patentee in most countries is the right to prevent others from making, using, selling, or distributing the patented invention without permission.<sup>[1]</sup> It is just a right to prevent others' use. A patent does not give the proprietor of the patent the right to *use* the patented invention, should it fall within the scope of an earlier patent.

Under the World Trade Organization's (WTO) Agreement on Trade-Related Aspects of Intellectual Property Rights, patents should be available in WTO member states for any inventions, in all fields of technology,<sup>[2]</sup> and the term of protection available should be the minimum twenty years.<sup>[3]</sup> Different types of patents may have varying patent terms (i.e., durations).



## Definition

The term *patent* usually refers to an exclusive right granted to anyone who invents any new, useful, and non-obvious process, machine, article of manufacture, or composition of matter, or any new and useful improvement thereof, and claims that right in a formal patent application. The additional qualification *utility patent* is used in the United States to distinguish it from other types of patents (e.g. design patents) but should not be confused with utility models granted by other countries. Examples of particular species of patents for inventions include biological patents, business method patents, chemical patents and software patents.

Some other types of intellectual property rights are referred to as *patents* in some jurisdictions: industrial design rights are called *design patents* in some jurisdictions (they protect the visual design of objects that are not purely utilitarian), plant breeders' rights are sometimes called *plant patents*, and utility models or *Gebrauchsmuster* are sometimes called *petty patents* or *innovation patents*. This article relates primarily to the patent for an invention, although so-called petty patents and utility models may also be granted for inventions.

Certain grants made by the monarch in pursuance of the royal prerogative were sometimes called *letters patent*, which was a government notice to the public of a grant of an exclusive right to ownership and possession. These were often grants of a patent-like monopoly and predate the modern origins of the patent system. For other uses of the term *patent* see notably land patents, which were land grants by early state governments in the USA, and printing patent, a precursor of modern copyright. These meanings reflect the original meaning of *letters patent* that had a broader scope than current usage.

## Etymology

The word *patent* originates from the Latin *patere*, which means "to lay open" (i.e., to make available for public inspection), and more directly as a shortened version of the term *letters patent*, which originally denoted an open for public reading royal decree granting exclusive rights to a person.

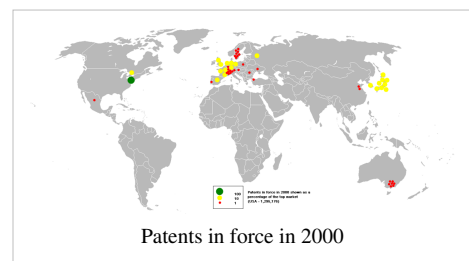
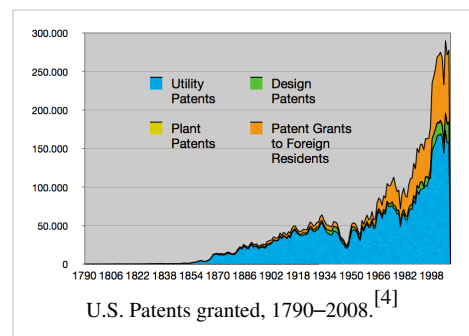
## History

In 500 BC, in the Greek city of Sybaris (located in what is now southern Italy), "encouragement was held out to all who should discover any new refinement in luxury, the profits arising from which were secured to the inventor by patent for the space of a year."<sup>[5]</sup>

The Florentine architect Filippo Brunelleschi received a three-year patent for a barge with hoisting gear, that carried marble along the Arno River in 1421.<sup>[6]</sup> In 1449, King Henry VI granted the first patent with a license of 20 years to John of Utynam for introducing the making of colored glass to England.<sup>[7]</sup>

Patents in the modern sense originated in 1474, when the Republic of Venice enacted a decree that new and inventive devices, once put into practice, had to be communicated to the Republic to obtain the right to prevent others from using them.<sup>[8]</sup>

England followed with the Statute of Monopolies in 1623 under King James I, which declared that patents could only be granted for "projects of new invention." During the reign of Queen Anne (1702–14), the lawyers of the English Court developed the requirement that a written description of the invention must be submitted.<sup>[9]</sup> The patent system in many other countries, including Australia, is based on British law and can be traced back to the Statute of Monopolies.



In France, patents were granted by the monarchy and by other institutions like the "Maison du Roi". The Academy examined novelty.<sup>[10]</sup> Examinations were generally done in secret with no requirement to publish a description of the invention. Actual use of the invention was deemed adequate disclosure to the public.<sup>[11]</sup> The modern French patent system was created during the Revolution in 1791. Patents were granted without examination since inventor's right was considered as a natural one<sup>[12]</sup>

In the United States, during the so-called colonial period and Articles of Confederation years (1778–89), several states adopted patent systems of their own. The first Congress adopted a Patent Act, in 1790, and the first patent was issued under this Act on July 31, 1790<sup>[13]</sup> (to Samuel Hopkins of Vermont for a potash production technique).

## Law

### Effects

A patent is not a right to practice or use the invention.<sup>[14]</sup> Rather, a patent provides the right to *exclude others*<sup>[14]</sup> from making, using, selling, offering for sale, or importing the patented invention for the term of the patent, which is usually 20 years from the filing date<sup>[3]</sup> subject to the payment of maintenance fees. A patent is, in effect, a limited property right that the government offers to inventors in exchange for their agreement to share the details of their inventions with the public. Like any other property right, it may be sold, licensed, mortgaged, assigned or transferred, given away, or simply abandoned.

The rights conveyed by a patent vary country-by-country. For example, in the United States, a patent covers research, except "purely philosophical" inquiry. A U.S. patent is infringed by any "making" of the invention, even a making that goes toward development of a new invention—which may itself become subject of a patent.

A patent being an exclusionary right does not, however, necessarily give the owner of the patent the right to exploit the patent. For example, many inventions are improvements of prior inventions that may still be covered by someone else's patent.<sup>[14]</sup> If an inventor takes an existing, patented mouse trap design, adds a new feature to make an improved mouse trap, and obtains a patent on the improvement, he or she can only legally build his or her improved mouse trap with permission from the patent holder of the original mouse trap, assuming the original patent is still in force. On the other hand, the owner of the improved mouse trap can exclude the original patent owner from using the improvement.

Some countries have "working provisions" that require the invention be exploited in the jurisdiction it covers. Consequences of not working an invention vary from one country to another, ranging from revocation of the patent rights to the awarding of a compulsory license awarded by the courts to a party wishing to exploit a patented invention. The patentee has the opportunity to challenge the revocation or license, but is usually required to provide evidence that the reasonable requirements of the public have been met by the working of invention.

## Enforcement

Patents can generally only be enforced through civil lawsuits (for example, for a U.S. patent, by an action for patent infringement in a United States federal court), although some countries (such as France and Austria) have criminal penalties for wanton infringement.<sup>[15]</sup> Typically, the patent owner will seek monetary compensation for past infringement, and will seek an injunction prohibiting the defendant from engaging in future acts of infringement. To prove infringement, the patent owner must establish that the accused infringer practices all the requirements of at least one of the claims of the patent. (In many jurisdictions the scope of the patent may not be limited to what is literally stated in the claims, for example due to the "doctrine of equivalents").

An important limitation on the ability of a patent owner to successfully assert the patent in civil litigation is the accused infringer's right to challenge the validity of that patent. Civil courts hearing patent cases can and often do declare patents not valid. A patent can be found invalid on grounds that are set out in the relevant patent legislation that vary between countries. Often, the grounds are a subset of requirements for patentability in the relevant country. Although an infringer is generally free to rely on any available ground of invalidity (such as a prior publication, for example), some countries have sanctions to prevent the same validity questions being relitigated. An example is the UK Certificate of contested validity.

The vast majority of patent rights, however, are not determined through litigation, but are resolved privately through patent licensing. Patent licensing agreements are effectively contracts in which the patent owner (the licensor) agrees to forgo their right to sue the licensee for infringement of the licensor's patent rights, usually in return for a royalty or other compensation. It is common for companies engaged in complex technical fields to enter into dozens of license agreements associated with the production of a single product. Moreover, it is equally common for competitors in such fields to license patents to each other under cross-licensing agreements in order to share the benefits of using each other's patented inventions.

## Ownership

In most countries, both natural persons and corporate entities may apply for a patent. In the United States, however, only the inventor(s) may apply for a patent although it may be assigned to a corporate entity subsequently<sup>[16]</sup> and inventors may be required to assign inventions to their employers under a contract of employment. In most European countries, ownership of an invention may pass from the inventor to their employer by rule of law if the invention was made in the course of the inventor's normal or specifically assigned employment duties, where an invention might reasonably be expected to result from carrying out those duties, or if the inventor had a special obligation to further the interests of the employer's company.<sup>[17]</sup>

The inventors, their successors or their assignees become the proprietors of the patent when and if it is granted. If a patent is granted to more than one proprietor, the laws of the country in question and any agreement between the proprietors may affect the extent to which each proprietor can exploit the patent. For example, in some countries, each proprietor may freely license or assign their rights in the patent to another person while the law in other countries prohibits such actions without the permission of the other proprietor(s).



The plate of the Martin ejector seat of the military aircraft, stating that the design is covered by multiple patents in Britain, South Africa, Canada and "others". Dübendorf Museum of Military Aviation.

The ability to assign ownership rights increases the liquidity of a patent as property. Inventors can obtain patents and then sell them to third parties.<sup>[18]</sup> The third parties then own the patents and have the same rights to prevent others from exploiting the claimed inventions, as if they had originally made the inventions themselves.

## **Governing laws**

The grant and enforcement of patents are governed by national laws, and also by international treaties, where those treaties have been given effect in national laws. Patents are, therefore, territorial in nature.

Commonly, a nation forms a patent office with responsibility for operating that nation's patent system, within the relevant patent laws. The patent office generally has responsibility for the grant of patents, with infringement being the remit of national courts.

There is a trend towards global harmonization of patent laws, with the World Trade Organization (WTO) being particularly active in this area. The TRIPs Agreement has been largely successful in providing a forum for nations to agree on an aligned set of patent laws. Conformity with the TRIPs agreement is a requirement of admission to the WTO and so compliance is seen by many nations as important. This has also led to many developing nations, which may historically have developed different laws to aid their development, enforcing patents laws in line with global practice.

A key international convention relating to patents is the Paris Convention for the Protection of Industrial Property, initially signed in 1883. The Paris Convention sets out a range of basic rules relating to patents, and although the convention does not have direct legal effect in all national jurisdictions, the principles of the convention are incorporated into all notable current patent systems. The most significant aspect of the convention is the provision of the right to claim priority: filing an application in any one member state of the Paris Convention preserves the right for one year to file in any other member state, and receive the benefit of the original filing date. Because the right to a patent is intensely date-driven, this right is fundamental to modern patent usage.

The authority for patent statutes in different countries varies. In the UK, substantive patent law is contained in the Patents Act 1977 as amended.<sup>[19]</sup> In the United States, the Constitution empowers Congress to make laws to "promote the Progress of Science and useful Arts..." The laws Congress passed are codified in Title 35 of the United States Code and created the United States Patent and Trademark Office.

In addition, there are international treaty procedures, such as the procedures under the European Patent Convention (EPC) [administered by the European Patent Organisation (EPOrg)], and the Patent Cooperation Treaty (PCT) (administered by WIPO and covering more than 140 countries), that centralize some portion of the filing and examination procedure. Similar arrangements exist among the member states of ARIPO and OAPI, the analogous treaties among African countries, and the nine CIS member states that have formed the Eurasian Patent Organization.

## **Application and prosecution**

A patent is requested by filing a written application at the relevant patent office. The person or company filing the application is referred to as "the applicant". The applicant may be the inventor or its assignee. The application contains a description of how to make and use the invention that must provide sufficient detail for a person skilled in the art (i.e., the relevant area of technology) to make and use the invention. In some countries there are requirements for providing specific information such as the usefulness of the invention, the best mode of performing the invention known to the inventor, or the technical problem or problems solved by the invention. Drawings illustrating the invention may also be provided.

The application also includes one or more claims, although it is not always a requirement to submit these when first filing the application. The claims set out what the applicant is seeking to protect in that they define what the patent owner has a right to exclude others from making, using, or selling, as the case may be. In other words, the claims define what a patent covers or the "scope of protection".

After filing, an application is often referred to as "patent pending". While this term does not confer legal protection, and a patent cannot be enforced until granted, it serves to provide warning to potential infringers that if the patent is issued, they may be liable for damages.<sup>[20] [21] [22]</sup>

For a patent to be granted, that is to take legal effect in a particular country, the patent application must meet the patentability requirements of that country. Most patent offices examine the application for compliance with these requirements. If the application does not comply, objections are communicated to the applicant or their patent agent or attorney and one or more opportunities to respond to the objections to bring the application into compliance are usually provided.

Once granted the patent is subject in most countries to renewal fees to keep the patent in force. These fees are generally payable on a yearly basis, although the US is a notable exception. Some countries or regional patent offices (e.g. the European Patent Office) also require annual renewal fees to be paid for a patent application before it is granted.

## Economics

### Rationale

There are four primary incentives embodied in the patent system: to invent in the first place; to disclose the invention once made; to invest the sums necessary to experiment, produce and market the invention; and to design around and improve upon earlier patents.<sup>[23]</sup>

1. Patents provide incentives for economically efficient research and development (R&D). A study conducted annually by the IPTS shows that the 2,000 largest global companies invested more than 430 billion euros in 2008<sup>[24]</sup> in their R&D departments. If the investments can be considered as inputs of R&D, patents are the outputs. Based on these groups, a project named Corporate Invention Board, had measured and analyzed the patent portfolios to produce an original picture<sup>[25]</sup> of their technological profiles. Without patents, R&D spending would be significantly less or eliminated altogether, limiting the possibility of technological advances or breakthroughs. Corporations would be much more conservative about the R&D investments they made, as third parties would be free to exploit any developments. This second justification is closely related to the basic ideas underlying traditional property rights.<sup>[23]</sup>
2. In accordance with the original definition of the term "patent," patents facilitate and encourage disclosure of innovations into the public domain for the common good. If inventors did not have the legal protection of patents, in many cases, they would prefer or tend to keep their inventions secret. Awarding patents generally makes the details of new technology publicly available, for exploitation by anyone after the patent expires, or for further improvement by other inventors. Furthermore, when a patent's term has expired, the public record ensures that the patentee's idea is not lost to humanity.<sup>[23]</sup>
3. In many industries (especially those with high fixed costs and either low marginal costs or low reverse engineering costs — computer processors, software, and pharmaceuticals for example), once an invention exists, the cost of commercialization (testing, tooling up a factory, developing a market, etc.) is far more than the initial conception cost. (For example, the internal "rule of thumb" at several computer companies in the 1980s was that post-R&D costs were 7-to-1). Unless there is some way to prevent copies from competing at the marginal cost of production, companies will not make that productization investment.<sup>[23]</sup>

One effect of modern patent usage is that a small-time inventor can use the exclusive right status to become a licensor. This allows the inventor to accumulate capital from licensing the invention and may allow innovation to occur because he or she may choose to not manage a manufacturing buildup for the invention. Thus the inventor's time and energy can be spent on pure innovation, allowing others to concentrate on manufacturability.<sup>[26]</sup>

Another effect of modern patent usage is to cause competitors to design around (or to "invent around" according to R S Praveen Raj<sup>[27]</sup>) each other's patents. This may promote healthy competition among manufacturers, resulting in



gradual improvements of the technology base. This may help augment national economies and confer better living standards to the citizens.

## Costs

Some of the costs to society associated with the granting of a patent are: the immediate costs associated with preparing the patent; patent office work; legal costs associated with prosecuting alleged infringements; business costs associated with those legal actions; increasing the cost of determining whether a method is covered by an existing patent, and reduced certainty in the result; restrictions on the use of the patented method (particularly in cases where the method is redeveloped independently).

The costs of preparing and filing a patent application, prosecuting it until grant and maintaining the patent vary from one jurisdiction to another, and may also be dependent upon the type and complexity of the invention, and on the type of patent.

The European Patent Office estimated in 2005 that the average cost of obtaining a European patent (via a Euro-direct application, i.e. not based on a PCT application) and maintaining the patent for a 10 year term was around 32 000 Euro.<sup>[28]</sup> Since the London Agreement entered into force on May 1, 2008, this estimation is however no longer up-to-date, since fewer translations are required.

In the United States, direct legal costs of patent litigation are on average in the order of a million dollars per case, not including associated business costs, based on an American Intellectual Property Law Association (AIPLA) survey of patent lawyers (2005), and court documents for a sample of 89 court cases where one side was ordered to pay the other side's legal fees.<sup>[29]</sup>

## Criticism

Patents have been criticized both in principle and in implementation.

In principle, patents have been criticized as a restraint of trade, for conferring a negative right upon a patent owner, permitting them to exclude competitors from using or exploiting the invention, even if the competitor subsequently develops the same invention independently. This may be subsequent to the date of invention, or to the priority date, depending upon the relevant patent law (see First to file and first to invent).<sup>[30]</sup>

As state-granted monopolies, patents have been criticized as inconsistent with free trade. On that basis, in 1869 the Netherlands abolished patents, and did not reintroduce them until 1912.<sup>[31]</sup>

In implementation, patents have been criticized for being granted on already-known inventions. In 1938, R. Buckminster Fuller wrote of the patent application process in the United States:<sup>[32]</sup>

At present, the files, are so extraordinarily complex and the items so multitudinous that a veritable army of governmental servants is required to attend them and sort them into some order of distinguishable categories to which reference may be made when corresponding with patent applicants for the purposes of examiner citation of "prior art" disclosure. This complexity makes it inevitable that the human-equation involved in government servants relative to carelessness or mechanical limitations should occasion the granting of multitudes of "probably" invalid patent claims.

Patents may hinder innovation as well in the case of "troll" entities. A holding company, pejoratively known as a "patent troll", owns a portfolio of patents, and sues others for infringement of these patents while doing little to develop the technology itself.<sup>[33]</sup> Other commentators suggest that patent trolls are not bad for the patent system at all but instead realign market participant incentives, make patents more liquid, and clear the patent market.<sup>[34]</sup>

Another theoretical problem with patent rights was proposed by law professors Michael Heller and Rebecca Sue Eisenberg. Based on Heller's theory of the tragedy of the anticommons, the authors argued that intellectual property rights may become so fragmented that, effectively, no one can take advantage of them as to do so would require an agreement between the owners of all of the fragments.<sup>[35]</sup>

Pharmaceutical patents prevent generic alternatives to enter the market until the patents expire, and thus maintains high prices for medication.<sup>[36]</sup> This can have significant effects in the developing world, as those who are most in need of basic essential medicines are unable to afford such high priced pharmaceuticals.<sup>[37]</sup> Critics also question the rationale that exclusive patent rights and the resulting high prices are required for pharmaceutical companies to recoup the large investments needed for research and development.<sup>[36]</sup> One study concluded that marketing expenditures for new drugs often doubled the amount that was allocated for research and development.<sup>[38]</sup> Other articles shed light on the problems of today's medical research. It sets wrong priorities in research and pricing, and pushes the state-run healthcare systems even of rich nations to their limits.<sup>[39]</sup>

In one response to these criticisms, one review concluded that less than 5 percent of medicines on the World Health Organization's list of essential drugs are under patent.<sup>[40]</sup> Also, the pharmaceutical industry has contributed US\$2 billion for healthcare in developing countries, providing HIV/AIDS drugs at lower cost or even free of charge in certain countries, and has used differential pricing and parallel imports to provide medication to the poor.<sup>[40]</sup> Other groups are investigating how social inclusion and equitable distribution of research and development findings can be obtained within the existing intellectual property framework, although these efforts have received less exposure.<sup>[40]</sup>

Brazil filed a proposal in 2010 with the WIPO Standing Committee on the Law of Patents about the imbalance of rights between IP title holders and the society as a whole with emphasis on the imbalance of benefits from strong IP rights between the few developed countries and the majority of member states.<sup>[41]</sup> Such imbalance is also recognized between freedom rights and exclusion rights by the computing profession.<sup>[42]</sup>

Concerns of a similar order have also been documented elsewhere, showing that public campaigns have had a concern for "preventing the over-reach" of IP protection including patent protection, and "to retain a public balance in property rights" of this kind.<sup>[43]</sup> The same source also noted the shift that had taken place away from the historical classification of such rights as "grants of privilege", towards referring to them in terms of property and rights; a change that encouraged a change of view of the relation of sovereign governments towards them, away from something that the government "may grant" towards a "duty to uphold them".<sup>[43]</sup>

## Alternatives

A defensive publication is the act of publishing a detailed description of a new invention without patenting it, so as to establish prior art and public identification as the creator/originator of an invention, although a defensive publication can also be anonymous. A defensive publication prevents others from later being able to patent the invention.

A trade secret is the act of not disclosing the methods by which a complex invention works or how a chemical is formulated. However, trade secrets do not provide legal protection like patents, and are vulnerable to reverse engineering and information leaks, i.e. breaches of confidentiality and corporate espionage.

## References

- [1] "Patents: Frequently Asked Questions" ([http://www.wipo.int/patentscope/en/patents\\_faq.html#protection](http://www.wipo.int/patentscope/en/patents_faq.html#protection)). World Intellectual Property Organization. . Retrieved 22 February 2009.
- [2] Article 27.1. of the TRIPs Agreement.
- [3] Article 33 of the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPs).
- [4] *U.S. Patent Activity 1790 to the Present* ([http://www.uspto.gov/web/offices/ac/ido/oeip/taf/h\\_counts.htm](http://www.uspto.gov/web/offices/ac/ido/oeip/taf/h_counts.htm)). USPTO. .
- [5] Charles Anthon, *A Classical Dictionary: Containing An Account Of The Principal Proper Names Mentioned in Ancient Authors, And Intended To Elucidate All The Important Points Connected With The Geography, History, Biography, Mythology, And Fine Arts Of The Greeks And Romans Together With An Account Of Coins, Weights, And Measures, With Tabular Values Of The Same*, Harper & Bros, 1841, p. 1273.
- [6] Christine MacLeod, *Inventing the Industrial Revolution: The English Patent System, 1660-1800*, Cambridge University Press, 2002, ISBN 0-521-89399-2, 9780521893992, p. 11.
- [7] "United Kingdom Patent Applications" (<http://w3.nexis.com/sources/scripts/info.pl?278252>). nexis.com. . Retrieved 29 November 2010.

- [8] Helmut Schippel (2001) (in **(German)**). *Die Anfänge des Erfinderschutzes in Venedig*, in: Uta Lindgren (Hrsg.): *Europäische Technik im Mittelalter. 800 bis 1400. Tradition und Innovation*, 4. Aufl. (<http://www.wolfgang-pfaller.de/venedig.htm>). Berlin: Wolfgang-Pfaller.de: Patentgesetz von Venedig, pp. 539–550. ISBN 3-7861-1748-9.
- [9] "History of Copyright" (<http://www.patent.gov.uk/about-history-copy.htm>). UK Intellectual Property Office. 2006. . Retrieved 2007-08-12.
- [10] MarketsAndPatents.com (<http://www.marketsandpatents.com/bulletin/IPB-10152009.html>), Nowotarski, Bakos, "A Short History of Private Patent Examination", Insurance IP Bulletin October 2009
- [11] Frank D. Prager, "Proposals for the Patent Act of 1790", *Journal of the Patent and Trademark Office Society*, March 1954, vol XXXVI, No. 3, pp 157 et Seq., citing J. Isore in *Revue Historique de Droit Francais*, 1937 pp. 117 et Seq.
- [12] Gabriel Galvez-Behar, *La République des inventeurs. Propriété et organisation de l'innovation en France, 1791-1922*, Presses universitaires de Rennes, 2008, ISBN 2-7535-0695-7, 9782753506954.
- [13] [http://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO2&Sect2=HITOFF&u=%2Fnetacgi%2FPTO%2Fsearch-adv.htm&r=1&p=1&f=G&l=50&d=PALL&S1=1790\\$.PD.&OS=ISD/\\$/1790&RS=ISD/1790\\$\\$](http://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO2&Sect2=HITOFF&u=%2Fnetacgi%2FPTO%2Fsearch-adv.htm&r=1&p=1&f=G&l=50&d=PALL&S1=1790$.PD.&OS=ISD/$/1790&RS=ISD/1790$$)
- [14] "A patent is not the grant of a right to make or use or sell. It does not, directly or indirectly, imply any such right. It grants only the right to exclude others. The supposition that a right to make is created by the patent grant is obviously inconsistent with the established distinctions between generic and specific patents, and with the well-known fact that a very considerable portion of the patents granted are in a field covered by a former relatively generic or basic patent, are tributary to such earlier patent, and cannot be practiced unless by license thereunder." - *Herman v. Youngstown Car Mfg. Co.*, 191 F. 579, 584-85, 112 CCA 185 (6th Cir. 1911)
- [15] DLA Piper Rudnick Gray Cary (2005). "Patent Litigation across Europe" (<http://cecollect.com/ve/ZZf3096aBBft91T940>). cecollect.com.
- [16] "Assignee (Company) Name" ([http://www.uspto.gov/web/patents/patog/week39/OG/help/help.htm#Assignee \(Company\) Name](http://www.uspto.gov/web/patents/patog/week39/OG/help/help.htm#Assignee%20(Company)%20Name)). *Help Page*. U.S. Patent and Trademark Office (USPTO). . Retrieved 2007-07-25.
- [17] See Section 39 of the UK Patents Act (<http://www.ipo.gov.uk/practice-sec-039.pdf>) as an example. The laws across Europe vary from country to country but are generally harmonised
- [18] Article 28.2 TRIPs ([http://www.wto.org/english/docs\\_e/legal\\_e/27-trips\\_04c\\_e.htm](http://www.wto.org/english/docs_e/legal_e/27-trips_04c_e.htm)): "*Patent owners shall also have the right to assign, or transfer by succession, the patent and to conclude licensing contracts.*".
- [19] United Kingdom law requiring no explicit authority due to the Supremacy of Parliament.
- [20] IP Australia website, *What does 'patent pending' mean?* (<http://www.ipaustralia.gov.au/media/pages/whatis/patents.htm>), Consulted on August 5, 2009.
- [21] USPTO web site, *Patent Marking and "Patent Pending"* (Excerpted from General Information Concerning Patents print brochure) (<http://www.uspto.gov/web/offices/pac/doc/general/patpend.htm>), Consulted on August 5, 2009.
- [22] UK Intellectual Property Office web site, *Display your rights* (<http://www.ipo.gov.uk/types/patent/p-manage/p-useenforce/p-displayrights.htm>), (under "IPO Home> Types of IP> Patents> Managing your patents> Using and enforcing") Consulted on August 5, 2009.
- [23] Howard T. Markey (chief judge of the United States Court of Customs and Patent Appeals and later of the Court of Appeals for the Federal Circuit), *Special Problems in Patent Cases*, 66 F.R.D. 529, 1975.
- [24] The 2009 EU Industrial R&D Investment Scoreboard ([http://iri.jrc.ec.europa.eu/research/scoreboard\\_2009.htm](http://iri.jrc.ec.europa.eu/research/scoreboard_2009.htm)) produced by the Institute for Prospective Technological Studies
- [25] Technological profiles for global companies (<http://www.corporateinventionboard.eu/en/corporate-rankings>) by analysing their patent portfolios
- [26] Stim, Rishand, "Profit from Your Idea: How to Make Smart Licensing Decisions", ISBN 1-4133-0450-8 (Published 2006)
- [27] <http://www.thehindubusinessline.com/2007/03/06/stories/2007030600492100.htm>
- [28] With the following assumptions: "18 pages (11 pages description, 3 pages claims, 4 pages drawings), 10 claims, patent validated in 6 countries (Germany, United Kingdom, France, Italy, Spain, Switzerland), excl. in-house preparation costs for the patentee" (the costs relate to European patents granted in 2002/2003), in European Patent Office, *The cost of a sample European patent - new estimates* ([http://www.european-patent-office.org/epo/new/cost\\_analysis\\_2005\\_en.pdf](http://www.european-patent-office.org/epo/new/cost_analysis_2005_en.pdf)), 2005, p. 1.
- [29] Bessen, James; Meurer, Michael James (2008). *Patent failure: how judges, bureaucrats, and lawyers put innovators at risk*. p. 132. ISBN 069113491X.. The containing chapter ("The Costs of Disputes") also tries to quantify associated business costs.
- [30] Gholz, Charles L. (December 2000). "First to File or First to Invent?" (<http://www.oblon.com/Pub/GholzFirsttoFile.html>). *Journal of the Patent and Trademark Office Society* **82**: 891. . Retrieved 2008-02-15.
- [31] Chang, Ha-Joon. "Kicking Away the Ladder: How the Economic and Intellectual Histories of Capitalism Have Been Re-Written to Justify Neo-Liberal Capitalism" (<http://www.paecon.net/PAEtexts/Chang1.htm>). *Post-Autistic Economics Review*. 4 September 2002: Issue 15, Article 3. Retrieved on 8 October 2008.
- [32] \*Fuller, R. Buckminster (1938). *Nine Chains to the Moon: An Adventure Story of Thought* (First ed.). Philadelphia: Lippincott. p. 277.
- [33] Quinion, Michael (June 17, 2006). "Patent Troll" (<http://www.worldwidewords.org/turnsofphrase/tp-pat1.htm>). *World Wide Words*. . Retrieved 2008-02-15.
- [34] McDonough III, James F. (January 31, 2006). "The Myth of the Patent Troll" ([http://papers.ssrn.com/sol3/papers.cfm?abstract\\_id=959945&rec=1&srcabs=980776](http://papers.ssrn.com/sol3/papers.cfm?abstract_id=959945&rec=1&srcabs=980776)). *The Myth of the Patent Troll*. . Retrieved 2010-01-17.

- [35] Heller, Michael; Eisenberg, Sue (May 1, 1998). "Can Patents Deter Innovation? The Anticommons in Biomedical Research". *Science* **280** (5364): 698–701. doi:10.1126/science.280.5364.698. PMID 9563938.
- [36] Banta, D.H. (2001). "Worldwide Interest in Global Access to Drugs". *Journal of the American Medical Association* **285** (22): 2844–46. doi:10.1001/jama.285.22.2844.
- [37] Ferreira, L. (2002). "Access to Affordable HIV/AIDS Drugs: The Human Rights Obligations of Multinational Pharmaceutical Corporations". *Fordham Law Review* **71** (3): 1133–79. PMID 12523370.
- [38] Barton, J.H.; Emanuel, E.J. (2005). "The Patents-Based Pharmaceutical Development Process: Rationale, Problems and Potential Reforms". *Journal of the American Medical Association* **294** (16): 2075–82. doi:10.1001/jama.294.16.2075. PMID 16249422.
- [39] Schaaber, Jörg (2010/11). "Misguided research" (<http://www.inwent.org/ez/articles/182681/index.en.shtml>). inwent.org. . Retrieved 29 November 2010.
- [40] Ghafele, Roya (August 2008). "Perceptions of Intellectual Property: A Review" ([http://www.ip-institute.org.uk/pdfs/Perceptions of IP.pdf](http://www.ip-institute.org.uk/pdfs/Perceptions%20of%20IP.pdf)). London: Intellectual Property Institute. . Retrieved 2009-11-05.
- [41] WIPO, SCP/14/7, Proposal from Brazil ([http://www.wipo.int/edocs/mdocs/patent\\_policy/en/scp\\_14/scp\\_14\\_7.pdf](http://www.wipo.int/edocs/mdocs/patent_policy/en/scp_14/scp_14_7.pdf)), Standing Committee on the Law of Patents, Fourteenth Session, January 20, 2010.
- [42] Kiesewetter-Köbinger, Swen (2010). "Programmers' Capital". *Computer* **43** (2): 108, 106–107. doi:10.1109/MC.2010.47.
- [43] Susan K Sell (2003), *Private Power, Public Law: The Globalization of Intellectual Property Rights*, Cambridge, 2003 (Cambridge University Press: Cambridge Studies in International Relations: 88); quoted from page 179, see also page 5.

## External links

- Directory of Intellectual Property Offices (<http://www.wipo.int/directory/en/urls.jsp>), maintained by World Intellectual Property Organization (WIPO)
- Useful links, "*Your guide to intellectual property information and services on the internet.*" (<http://www.epo.org/topics/ip-webguide.html>), maintained by the European Patent Office
- OECD Patent statistics ([http://stats.oecd.org/Index.aspx?DataSetCode=PATS\\_IPC](http://stats.oecd.org/Index.aspx?DataSetCode=PATS_IPC))

## Problem solving

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**Problem solving** is a mental process and is part of the larger problem process that includes problem finding and problem shaping. Considered the most complex of all intellectual functions, problem solving has been defined as higher-order cognitive process that requires the modulation and control of more routine or fundamental skills.<sup>[1]</sup> Problem solving occurs when an organism or an artificial intelligence system needs to move from a given state to a desired goal state.

## Overview

The nature of human problem solving methods has been studied by psychologists over the past hundred years. There are several methods of studying problem solving, including; introspection, behaviorism, simulation, computer modeling and experiment.

Beginning with the early experimental work of the Gestaltists in Germany (e.g. Duncker, 1935<sup>[2]</sup>), and continuing through the 1960s and early 1970s, research on problem solving typically conducted relatively simple, laboratory tasks (e.g. Duncker's "X-ray" problem; Ewert & Lambert's 1932 "disk" problem, later known as Tower of Hanoi) that appeared novel to participants (e.g. Mayer, 1992<sup>[3]</sup>). Various reasons account for the choice of simple novel tasks: they had clearly defined optimal solutions, they were solvable within a relatively short time frame, researchers could trace participants' problem-solving steps, and so on. The researchers made the underlying assumption, of course, that simple tasks such as the Tower of Hanoi captured the main properties of "real world" problems, and that the cognitive processes underlying participants' attempts to solve simple problems were representative of the processes engaged in when solving "real world" problems. Thus researchers used simple problems for reasons of convenience, and thought generalizations to more complex problems would become possible. Perhaps the best-known and most impressive example of this line of research remains the work by Allen Newell and Herbert

Simon [4].

Simple laboratory-based tasks can be useful in explicating the steps of logic and reasoning that underlie problem solving; however, they omit the complexity and emotional valence of "real-world" problems. In clinical psychology, researchers have focused on the role of emotions in problem solving (D'Zurilla & Goldfried, 1971; D'Zurilla & Nezu, 1982), demonstrating that poor emotional control can disrupt focus on the target task and impede problem resolution (Rath, Langenbahn, Simon, Sherr, & Diller, 2004). In this conceptualization, human problem solving consists of two related processes: problem orientation, the motivational/attitudinal/affective approach to problematic situations and problem-solving skills, the actual cognitive-behavioral steps, which, if successfully implemented, lead to effective problem resolution. Working with individuals with frontal lobe injuries, neuropsychologists have discovered that deficits in emotional control and reasoning can be remediated, improving the capacity of injured persons to resolve everyday problems successfully (Rath, Simon, Langenbahn, Sherr, & Diller, 2003).

## Europe

In Europe, two main approaches have surfaced, one initiated by Donald Broadbent (1977; see Berry & Broadbent, 1995) in the United Kingdom and the other one by Dietrich Dörner (1975, 1985; see Dörner & Wearing, 1995) in Germany. The two approaches have in common an emphasis on relatively complex, semantically rich, computerized laboratory tasks, constructed to resemble real-life problems. The approaches differ somewhat in their theoretical goals and methodology, however. The tradition initiated by Broadbent emphasizes the distinction between cognitive problem-solving processes that operate under awareness versus outside of awareness, and typically employs mathematically well-defined computerized systems. The tradition initiated by Dörner, on the other hand, has an interest in the interplay of the cognitive, motivational, and social components of problem solving, and utilizes very complex computerized scenarios that contain up to 2,000 highly interconnected variables (e.g., Dörner, Kreuzig, Reither & Stäudel's 1983 LOHHAUSEN project; Ringelband, Misiak & Kluwe, 1990). Buchner (1995) describes the two traditions in detail.

To sum up, researchers' realization that problem-solving processes differ across knowledge domains and across levels of expertise (e.g. Sternberg, 1995) and that, consequently, findings obtained in the laboratory cannot necessarily generalize to problem-solving situations outside the laboratory, has during the past two decades led to an emphasis on real-world problem solving. This emphasis has been expressed quite differently in North America and Europe, however. Whereas North American research has typically concentrated on studying problem solving in separate, natural knowledge domains, much of the European research has focused on novel, complex problems, and has been performed with computerized scenarios (see Funke, 1991, for an overview).

## USA and Canada

In North America, initiated by the work of Herbert Simon on learning by doing in semantically rich domains (e.g. Anzai & Simon, 1979; Bhaskar & Simon, 1977), researchers began to investigate problem solving separately in different natural knowledge domains – such as physics, writing, or chess playing – thus relinquishing their attempts to extract a global theory of problem solving (e.g. Sternberg & Frensch, 1991). Instead, these researchers have frequently focused on the development of problem solving within a certain domain, that is on the development of expertise (e.g. Anderson, Boyle & Reiser, 1985; Chase & Simon, 1973; Chi, Feltovich & Glaser, 1981).

Areas that have attracted rather intensive attention in North America include such diverse fields as:

- Problem Solving (Kepner & Tregoe, 1958)
- Reading (Stanovich & Cunningham, 1991)
- Writing (Bryson, Bereiter, Scardamalia & Joram, 1991)
- Calculation (Sokol & McCloskey, 1991)
- Political decision making (Voss, Wolfe, Lawrence & Engle, 1991)

- Problem Solving for Business (Cornell, 2010)
- Managerial problem solving (Wagner, 1991)
- Lawyers' reasoning (Amsel, Langer & Loutzenhiser, 1991)
- Mechanical problem solving (Hegarty, 1991)
- Problem solving in electronics (Lesgold & Lajoie, 1991)
- Computer skills (Kay, 1991)
- Game playing (Frensch & Sternberg, 1991)
- Personal problem solving (Heppner & Krauskopf, 1987)
- Mathematical problem solving (Polya, 1945; Schoenfeld, 1985)
- Social problem solving (D'Zurilla & Goldfreid, 1971; D'Zurilla & Nezu, 1982)
- Problem solving for innovations and inventions: TRIZ (Altshuller, 1973, 1984, 1994)

## Characteristics of difficult problems

As elucidated by Dietrich Dörner and later expanded upon by Joachim Funke, difficult problems have some typical characteristics that can be summarized as follows:

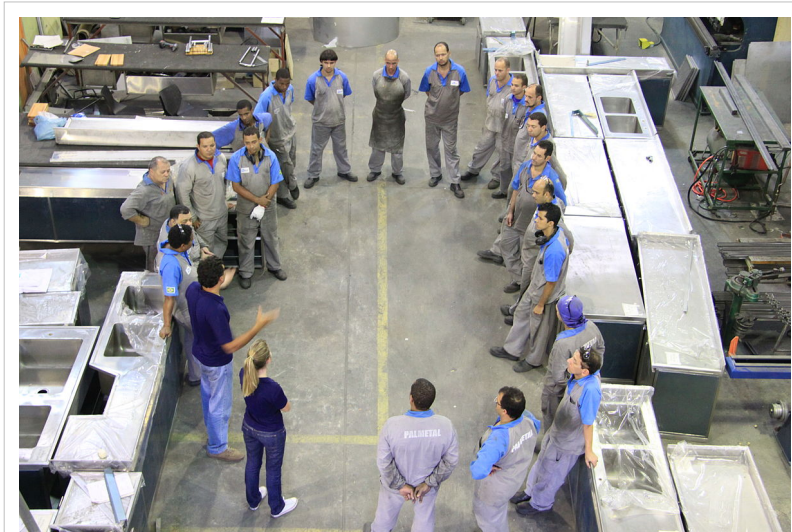
- Intransparency (lack of clarity of the situation)
  - commencement opacity
  - continuation opacity
- Polytelicity (multiple goals)
  - inexpressiveness
  - opposition
  - transience
- Complexity (large numbers of items, interrelations and decisions)
  - enumerability
  - connectivity (hierarchy relation, communication relation, allocation relation)
  - heterogeneity
- Dynamics (time considerations)
  - temporal constraints
  - temporal sensitivity
  - phase effects
  - dynamic unpredictability

The resolution of difficult problems requires a direct attack on each of these characteristics that are encountered.

In reform mathematics, greater emphasis is placed on problem solving relative to basic skills, where basic operations can be done with calculators. However some "problems" may actually have standard solutions taught in higher grades. For example, kindergarteners could be asked how many fingers are there on all the gloves of 3 children, which can be solved with multiplication.<sup>[5]</sup>

## Problem-solving techniques

- Abstraction: solving the problem in a model of the system before applying it to the real system
- Analogy: using a solution that solved an analogous problem
- Brainstorming: (especially among groups of people) suggesting a large number of solutions or ideas and combining and developing them until an optimum is found
- Divide and conquer: breaking down a large, complex problem into smaller, solvable problems
- Hypothesis testing: assuming a possible explanation to the problem and trying to prove (or, in some contexts, disprove) the assumption
- Lateral thinking: approaching solutions indirectly and creatively
- Means-ends analysis: choosing an action at each step to move closer to the goal
- Method of focal objects: synthesizing seemingly non-matching characteristics of different objects into something new
- Morphological analysis: assessing the output and interactions of an entire system
- Reduction: transforming the problem into another problem for which solutions exist
- Research: employing existing ideas or adapting existing solutions to similar problems
- Root cause analysis: eliminating the cause of the problem
- Trial-and-error: testing possible solutions until the right one is found



Training meeting about sustainable design. The photo shows a training meeting with factory workers in a stainless steel ecodesign company from Rio de Janeiro, Brazil. These types of meetings encourage brainstorming on the shop floor.

"A solution, to be a solution, must share some of the problems characteristics." Richard L Kempe

## Problem-solving methodologies

- Eight Disciplines Problem Solving
- 5 $\Phi$  (IAPIE)
- GROW model
- *How to solve it*
- Kepner-Tregoe
- Southbeach Notation
- PDCA
- RPR Problem Diagnosis
- TRIZ (Teoriya Resheniya Izobretatelskikh Zadatch, "theory of solving inventor's problems")
- WebKaizen

## Example applications

Problem solving is of crucial importance in engineering when products or processes fail, so corrective action can be taken to prevent further failures. Perhaps of more value, problem solving can be applied to a product or process prior to an actual fail event i.e. a potential problem can be predicted, analyzed and mitigation applied so the problem never actually occurs. Techniques like Failure Mode Effects Analysis can be used to proactively reduce the likelihood of problems occurring. Forensic engineering is an important technique of failure analysis which involves tracing product defects and flaws. Corrective action can then be taken to prevent further failures.

## Notes

- [1] Goldstein F. C., & Levin H. S. (1987). Disorders of reasoning and problem-solving ability. In M. Meier, A. Benton, & L. Diller (Eds.), *Neuropsychological rehabilitation*. London: Taylor & Francis Group.
- [2] Duncker, K. (1935). *Zur Psychologie des produktiven Denkens* [The psychology of productive thinking]. Berlin: Julius Springer.
- [3] Mayer, R. E. (1992). *Thinking, problem solving, cognition*. Second edition. New York: W. H. Freeman and Company.
- [4] \*Newell, A., & Simon, H. A. (1972). *Human problem solving*. Englewood Cliffs, NJ: Prentice-Hall.
- [5] 2007 Draft, Washington State Revised Mathematics Standard

## References

- Amsel, E., Langer, R., & Loutzenhiser, L. (1991). Do lawyers reason differently from psychologists? A comparative design for studying expertise. In R. J. Sternberg & P. A. Frensch (Eds.), *Complex problem solving: Principles and mechanisms* (pp. 223-250). Hillsdale, NJ: Lawrence Erlbaum Associates. ISBN 978-0-8058-1783-6
- Anderson, J. R., Boyle, C. B., & Reiser, B. J. (1985). "Intelligent tutoring systems". *Science* **228** (4698): 456–462. doi:10.1126/science.228.4698.456. PMID 17746875.
- Anzai, K., & Simon, H. A. (1979) (1979). "The theory of learning by doing". *Psychological Review* **86** (2): 124–140. doi:10.1037/0033-295X.86.2.124. PMID 493441.
- Beckmann, J. F., & Guthke, J. (1995). Complex problem solving, intelligence, and learning ability. In P. A. Frensch & J. Funke (Eds.), *Complex problem solving: The European Perspective* (pp. 177-200). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Berry, D. C., & Broadbent, D. E. (1995). Implicit learning in the control of complex systems: A reconsideration of some of the earlier claims. In P.A. Frensch & J. Funke (Eds.), *Complex problem solving: The European Perspective* (pp. 131-150). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Bhaskar, R., & Simon, H. A. (1977). Problem solving in semantically rich domains: An example from engineering thermodynamics. *Cognitive Science*, 1, 193-215.
- Brehmer, B. (1995). Feedback delays in dynamic decision making. In P. A. Frensch & J. Funke (Eds.), *Complex problem solving: The European Perspective* (pp. 103-130). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Brehmer, B., & Dörner, D. (1993). Experiments with computer-simulated microworlds: Escaping both the narrow straits of the laboratory and the deep blue sea of the field study. *Computers in Human Behavior*, 9, 171-184.
- Broadbent, D. E. (1977). Levels, hierarchies, and the locus of control. *Quarterly Journal of Experimental Psychology*, 29, 181-201.
- Bryson, M., Bereiter, C., Scardamalia, M., & Joram, E. (1991). Going beyond the problem as given: Problem solving in expert and novice writers. In R. J. Sternberg & P. A. Frensch (Eds.), *Complex problem solving: Principles and mechanisms* (pp. 61-84). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Buchner, A. (1995). Theories of complex problem solving. In P. A. Frensch & J. Funke (Eds.), *Complex problem solving: The European Perspective* (pp. 27-63). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Buchner, A., Funke, J., & Berry, D. C. (1995). Negative correlations between control performance and verbalizable knowledge: Indicators for implicit learning in process control tasks? *Quarterly Journal of Experimental Psychology*, 48A, 166-187.



- Chase, W. G., & Simon, H. A. (1973). Perception in chess. *Cognitive Psychology*, 4, 55-81.
- Chi, M. T. H., Feltovich, P. J., & Glaser, R. (1981). "Categorization and representation of physics problems by experts and novices" (<http://www.usabilityviews.com/uv007206.html>). *Cognitive Science* 5 (2): 121-152. doi:10.1207/s15516709cog0502\_2.
- Cornell, Kate (2010). *WebKaizen, Better Faster Cheaper Problem Solving for Business*. Omaha NE: Prevail Digital Publishing. ISBN 978-0-9831102-1-7.
- Dörner, D. (1975). Wie Menschen eine Welt verbessern wollten [How people wanted to improve the world]. *Bild der Wissenschaft*, 12, 48-53.
- Dörner, D. (1985). Verhalten, Denken und Emotionen [Behavior, thinking, and emotions]. In L. H. Eckensberger & E. D. Lantermann (Eds.), *Emotion und Reflexivität* (pp. 157-181). München, Germany: Urban & Schwarzenberg.
- Dörner, D. (1992). Über die Philosophie der Verwendung von Mikrowelten oder "Computerszenarios" in der psychologischen Forschung [On the proper use of microworlds or "computer scenarios" in psychological research]. In H. Gundlach (Ed.), *Psychologische Forschung und Methode: Das Versprechen des Experiments. Festschrift für Werner Traxel* (pp. 53-87). Passau, Germany: Passavia-Universitäts-Verlag.
- Dörner, D., Kreuzig, H. W., Reither, F., & Stäudel, T. (Eds.). (1983). *Lohhausen. Vom Umgang mit Unbestimmtheit und Komplexität* [Lohhausen. On dealing with uncertainty and complexity]. Bern, Switzerland: Hans Huber.
- Dörner, D., & Wearing, A. (1995). Complex problem solving: Toward a (computer-simulated) theory. In P. A. Frensch & J. Funke (Eds.), *Complex problem solving: The European Perspective* (pp. 65-99). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Duncker, K. (1935). *Zur Psychologie des produktiven Denkens* [The psychology of productive thinking]. Berlin: Julius Springer.
- Ewert, P. H., & Lambert, J. F. (1932). Part II: The effect of verbal instructions upon the formation of a concept. *Journal of General Psychology*, 6, 400-411.
- Eyferth, K., Schömann, M., & Widowski, D. (1986). Der Umgang von Psychologen mit Komplexität [On how psychologists deal with complexity]. *Sprache & Kognition*, 5, 11-26.
- Frensch, P. A., & Funke, J. (Eds.). (1995). *Complex problem solving: The European Perspective*. Hillsdale, NJ: Lawrence Erlbaum Associates.
- Frensch, P. A., & Sternberg, R. J. (1991). Skill-related differences in game playing. In R. J. Sternberg & P. A. Frensch (Eds.), *Complex problem solving: Principles and mechanisms* (pp. 343-381). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Funke, J. (1991). Solving complex problems: Human identification and control of complex systems. In R. J. Sternberg & P. A. Frensch (Eds.), *Complex problem solving: Principles and mechanisms* (pp. 185-222). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Funke, J. (1993). Microworlds based on linear equation systems: A new approach to complex problem solving and experimental results. In G. Strube & K.-F. Wender (Eds.), *The cognitive psychology of knowledge* (pp. 313-330). Amsterdam: Elsevier Science Publishers.
- Funke, J. (1995). Experimental research on complex problem solving. In P. A. Frensch & J. Funke (Eds.), *Complex problem solving: The European Perspective* (pp. 243-268). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Funke, U. (1995). Complex problem solving in personnel selection and training. In P. A. Frensch & J. Funke (Eds.), *Complex problem solving: The European Perspective* (pp. 219-240). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Goldstein F. C., & Levin H. S. (1987). Disorders of reasoning and problem-solving ability. In M. Meier, A. Benton, & L. Diller (Eds.), *Neuropsychological rehabilitation*. London: Taylor & Francis Group.

- Groner, M., Groner, R., & Bischof, W. F. (1983). Approaches to heuristics: A historical review. In R. Groner, M. Groner, & W. F. Bischof (Eds.), *Methods of heuristics* (pp. 1-18). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Halpern, Diane F. (2002). *Thought & Knowledge*. Lawrence Erlbaum Associates. Worldcat Library Catalog (<http://worldcat.org/oclc/50065032&tab=holdings>)
- Hayes, J. (1980). *The complete problem solver*. Philadelphia: The Franklin Institute Press.
- Hegarty, M. (1991). Knowledge and processes in mechanical problem solving. In R. J. Sternberg & P. A. Frensch (Eds.), *Complex problem solving: Principles and mechanisms* (pp. 253-285). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Heppner, P. P., & Krauskopf, C. J. (1987). An information-processing approach to personal problem solving. *The Counseling Psychologist*, 15, 371-447.
- Huber, O. (1995). Complex problem solving as multi stage decision making. In P. A. Frensch & J. Funke (Eds.), *Complex problem solving: The European Perspective* (pp. 151-173). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Hübner, R. (1989). Methoden zur Analyse und Konstruktion von Aufgaben zur kognitiven Steuerung dynamischer Systeme [Methods for the analysis and construction of dynamic system control tasks]. *Zeitschrift für Experimentelle und Angewandte Psychologie*, 36, 221-238.
- Hunt, E. (1991). Some comments on the study of complexity. In R. J. Sternberg, & P. A. Frensch (Eds.), *Complex problem solving: Principles and mechanisms* (pp. 383-395). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Hussy, W. (1985). Komplexes Problemlösen - Eine Sackgasse? [Complex problem solving - a dead end?]. *Zeitschrift für Experimentelle und Angewandte Psychologie*, 32, 55-77.
- Kay, D. S. (1991). Computer interaction: Debugging the problems. In R. J. Sternberg & P. A. Frensch (Eds.), *Complex problem solving: Principles and mechanisms* (pp. 317-340). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Kluwe, R. H. (1993). Knowledge and performance in complex problem solving. In G. Strube & K.-F. Wender (Eds.), *The cognitive psychology of knowledge* (pp. 401-423). Amsterdam: Elsevier Science Publishers.
- Kluwe, R. H. (1995). Single case studies and models of complex problem solving. In P. A. Frensch & J. Funke (Eds.), *Complex problem solving: The European Perspective* (pp. 269-291). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Kolb, S., Petzing, F., & Stumpf, S. (1992). Komplexes Problemlösen: Bestimmung der Problemlösequalität von Probanden mittels Verfahren des Operations Research ? ein interdisziplinärer Ansatz [Complex problem solving: determining the quality of human problem solving by operations research tools - an interdisciplinary approach]. *Sprache & Kognition*, 11, 115-128.
- Krems, J. F. (1995). Cognitive flexibility and complex problem solving. In P. A. Frensch & J. Funke (Eds.), *Complex problem solving: The European Perspective* (pp. 201-218). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Lesgold, A., & Lajoie, S. (1991). Complex problem solving in electronics. In R. J. Sternberg & P. A. Frensch (Eds.), *Complex problem solving: Principles and mechanisms* (pp. 287-316). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Mayer, R. E. (1992). *Thinking, problem solving, cognition*. Second edition. New York: W. H. Freeman and Company.
- Müller, H. (1993). *Komplexes Problemlösen: Reliabilität und Wissen* [Complex problem solving: Reliability and knowledge]. Bonn, Germany: HoloS.
- Newell, A., & Simon, H. A. (1972). *Human problem solving*. Englewood Cliffs, NJ: Prentice-Hall.
- Paradies, M.W., & Unger, L. W. (2000). *TapRoot - The System for Root Cause Analysis, Problem Investigation, and Proactive Improvement*. Knoxville, TN: System Improvements.
- Putz-Osterloh, W. (1993). Strategies for knowledge acquisition and transfer of knowledge in dynamic tasks. In G. Strube & K.-F. Wender (Eds.), *The cognitive psychology of knowledge* (pp. 331-350). Amsterdam: Elsevier

Science Publishers.

- Riefer, D.M., & Batchelder, W.H. (1988). Multinomial modeling and the measurement of cognitive processes. *Psychological Review*, 95, 318-339.
- Ringelband, O. J., Misiak, C., & Kluwe, R. H. (1990). Mental models and strategies in the control of a complex system. In D. Ackermann, & M. J. Tauber (Eds.), *Mental models and human-computer interaction* (Vol. 1, pp. 151-164). Amsterdam: Elsevier Science Publishers.
- Schaub, H. (1993). *Modellierung der Handlungsorganisation*. Bern, Switzerland: Hans Huber.
- Sokol, S. M., & McCloskey, M. (1991). Cognitive mechanisms in calculation. In R. J. Sternberg & P. A. Frensch (Eds.), *Complex problem solving: Principles and mechanisms* (pp. 85-116). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Stanovich, K. E., & Cunningham, A. E. (1991). Reading as constrained reasoning. In R. J. Sternberg & P. A. Frensch (Eds.), *Complex problem solving: Principles and mechanisms* (pp. 3-60). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Sternberg, R. J. (1995). Conceptions of expertise in complex problem solving: A comparison of alternative conceptions. In P. A. Frensch & J. Funke (Eds.), *Complex problem solving: The European Perspective* (pp. 295-321). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Sternberg, R. J., & Frensch, P. A. (Eds.). (1991). *Complex problem solving: Principles and mechanisms*. Hillsdale, NJ: Lawrence Erlbaum Associates.
- Strauß, B. (1993). *Konfundierungen beim Komplexen Problemlösen. Zum Einfluß des Anteils der richtigen Lösungen (ArL) auf das Problemlöseverhalten in komplexen Situationen* [Confoundations in complex problem solving. On the influence of the degree of correct solutions on problem solving in complex situations]. Bonn, Germany: Holos.
- Strohschneider, S. (1991). Kein System von Systemen! Kommentar zu dem Aufsatz "Systemmerkmale als Determinanten des Umgangs mit dynamischen Systemen" von Joachim Funke [No system of systems! Reply to the paper "System features as determinants of behavior in dynamic task environments" by Joachim Funke]. *Sprache & Kognition*, 10, 109-113.
- Van Lehn, K. (1989). Problem solving and cognitive skill acquisition. In M. I. Posner (Ed.), *Foundations of cognitive science* (pp. 527-579). Cambridge, MA: MIT Press.
- Voss, J. F., Wolfe, C. R., Lawrence, J. A., & Engle, R. A. (1991). From representation to decision: An analysis of problem solving in international relations. In R. J. Sternberg & P. A. Frensch (Eds.), *Complex problem solving: Principles and mechanisms* (pp. 119-158). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Wagner, R. K. (1991). Managerial problem solving. In R. J. Sternberg & P. A. Frensch (Eds.), *Complex problem solving: Principles and mechanisms* (pp. 159-183). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Wisconsin Educational Media Association. (1993). "Information literacy: A position paper on information problem-solving." Madison, WI: WEMA Publications. (ED 376 817). (Portions adapted from Michigan State Board of Education's Position Paper on Information Processing Skills, 1992).
- Altshuller, Genrich (1973). *Innovation Algorithm*. Worcester, MA: Technical Innovation Center. ISBN 0-9640740-2-8.
- Altshuller, Genrich (1984). *Creativity as an Exact Science*. New York, NY: Gordon & Breach. ISBN 0-677-21230-5.
- Altshuller, Genrich (1994). *And Suddenly the Inventor Appeared*. translated by Lev Shulyak. Worcester, MA: Technical Innovation Center. ISBN 0-9640740-1-X.
- D'Zurilla, T. J., & Goldfried, M. R. (1971). Problem solving and behavior modification. *Journal of Abnormal Psychology*, 78, 107-126.
- D'Zurilla, T. J., & Nezu, A. M. (1982). Social problem solving in adults. In P. C. Kendall (Ed.), *Advances in cognitive-behavioral research and therapy* (Vol. 1, pp. 201-274). New York: Academic Press.

- Rath J. F.; Langenbahn D. M.; Simon D.; Sherr R. L.; Fletcher J.; Diller L. (2004). The construct of problem solving in higher level neuropsychological assessment and rehabilitation. *Archives of Clinical Neuropsychology*, 19, 613-635. doi:10.1016/j.acn.2003.08.006
- Rath, J. F.; Simon, D.; Langenbahn, D. M.; Sherr, R. L.; Diller, L. (2003). Group treatment of problem-solving deficits in outpatients with traumatic brain injury: A randomised outcome study. *Neuropsychological Rehabilitation*, 13, 461-488.

## External links

- Computer Skills for Information Problem-Solving: Learning and Teaching Technology in Context (<http://www.ericdigests.org/1996-4/skills.htm>)
- Problem solving-Elementary level ([http://moodle.ed.uiuc.edu/wiked/index.php/Problem\\_solving-Elementary\\_level](http://moodle.ed.uiuc.edu/wiked/index.php/Problem_solving-Elementary_level))
- CROP (Communities Resolving Our Problems) (<http://ceap.wcu.edu/houghton/Learner/basicidea.html>)
- The Altshuller Institute for TRIZ Studies, Worcester, MA (<http://www.aitriz.org>)

# TRIZ

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**TRIZ** ((pronounced /'tri:z/), Russian: Теория решения изобретательских задач (*Teoriya Resheniya Izobretatelskikh Zadatch*)) is "a problem-solving, analysis and forecasting tool derived from the study of patterns of invention in the global patent literature".<sup>[1]</sup> It was developed by the Soviet inventor and science fiction author Genrich Altshuller and his colleagues, beginning in 1946. In English the name is typically rendered as "the **Theory of Inventive Problem Solving**",<sup>[2]</sup> <sup>[3]</sup> and occasionally goes by the English acronym **TIPS**.

Following Altshuller's insight, the Theory developed on a foundation of extensive research covering hundreds of thousands of inventions across many different fields to produce a theory which defines generalisable patterns in the nature of inventive solutions and the distinguishing characteristics of the problems that these inventions have overcome.

An important part of the Theory has been devoted to revealing patterns of evolution and one of the objectives which has been pursued by leading practitioners of TRIZ has been the development of an algorithmic approach to the invention of new systems, and the refinement of existing ones.

The Theory includes a practical methodology, tool sets, a knowledge base, and model-based technology for generating new ideas and solutions for problem solving. It is intended for application in problem formulation, system analysis, failure analysis, and patterns of system evolution.

## History

TRIZ in its classical form was developed by the Soviet inventor and science fiction writer Genrich Altshuller and his associates. He started developing TRIZ in 1946 while working in the "Inventions Inspection" department of the Caspian Sea flotilla of the Soviet Navy. His job was to help with the initiation of invention proposals, to rectify and document them and prepare applications to the patent office. During this time he realised that a problem requires an inventive solution if there is an unresolved contradiction in the sense that improving one parameter impacts negatively on another. He later called these "technical contradictions".

His work on what later resulted in TRIZ was interrupted in 1950 by his arrest and sentencing to 25 years in the Gulag. According to one source the arrest was partially triggered by letters which he and Raphael Shapiro sent to Stalin, ministers and newspapers about certain decisions made by the Soviet Government, which they believed were erroneous.<sup>[4]</sup> Altshuller and Shapiro were freed following Stalin's death in 1953<sup>[5]</sup> and returned to Baku.

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The first paper on TRIZ titled "On the psychology of inventive creation" was published in 1956 in "Issues in Psychology" (Voprosi Psichologii) journal.<sup>[6]</sup>

By 1969 Altshuller had reviewed about 40,000 patent abstracts in order to find out in what way the innovation had taken place and developed the concept of technical contradictions, the concept of Ideality of a system, contradiction matrix, and 40 Principles of Invention. In the years that followed he developed the concept of physical contradictions, SuField Analysis, Standard Solutions, and several Laws of Technical Systems Evolution, and numerous other theoretical and practical approaches.

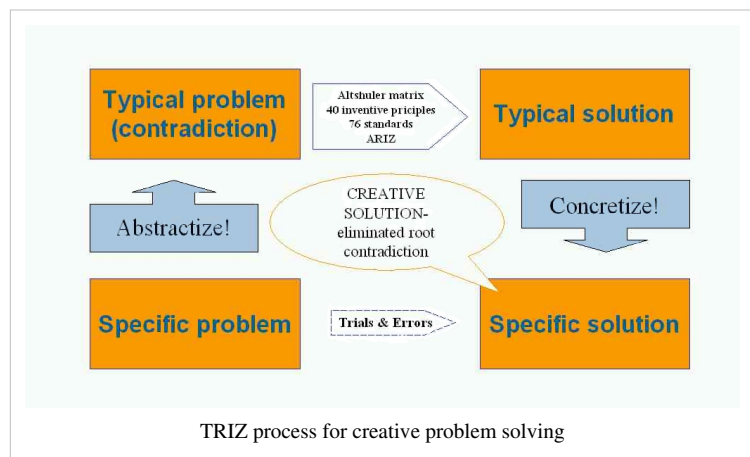
In 1971 Altshuller convinced The Inventors Society to establish in Baku the first TRIZ teaching facility called the Azerbaijan Public Institute for Inventive Creation and the first TRIZ research lab called The Public Lab for Inventive Creation. Altshuller was appointed the head of the lab by the Society. The lab incubated the TRIZ movement and in the years that followed other TRIZ teaching institutes were established in all major cities of the USSR. In 1989 the TRIZ Association was formed, with Altshuller chosen as President.

Following the end of the cold war, the waves of emigrants from the former Soviet Union brought TRIZ to other countries and drew attention to it overseas.<sup>[7]</sup> In 1995 the Altshuller Institute for TRIZ Studies was established in Boston, USA.

## Basic principles of TRIZ

TRIZ presents a systematic approach for analysing the kind of challenging problems where inventiveness is needed and provides a range of strategies and tools for finding inventive solutions. One of the earliest findings of the massive research on which the theory is based is that the vast majority of problems that require inventive solutions typically reflect a need to overcome a dilemma or a trade-off between two contradictory elements. The central purpose of TRIZ-based analysis is to systematically apply the strategies and tools to find superior solutions that overcome the need for a compromise or trade-off between the two elements.

By the early 1970s two decades of research covering hundreds of thousands of patents had confirmed Altshuller's initial insight about the patterns of inventive solutions and one of the first analytical tools was published in the form of 40 Inventive Principles, which could account for virtually all of those patents that presented truly inventive solutions. Following this approach the "Typical solution" shown in the diagram can be found by defining the contradiction which needs to be resolved and systematically considering which of the 40 principles may be applied to provide a specific solution which will overcome the "contradiction" in the problem at hand, enabling a solution that is closer to the "ultimate ideal result".



The combination of all of these concepts together – the analysis of the contradiction, the pursuit of an ideal solution and the search for one or more of the Principles which will overcome the contradiction, are the key elements in a process which is designed to help the inventor to engage in the process with purposefulness and focus.

One of the tools which evolved as an extension of the 40 Principles was a Contradiction Matrix in which the contradictory elements of a problem were categorized according to a list of 39 factors which could impact on each other. The combination of each pairing of these 39 elements is set out in a matrix (for example, the weight of a stationary object, the use of energy by a moving object, the ease of repair etc.) Each of the 39 elements is represented down the rows and across the columns (as the negatively affected element) and based upon the research and analysis

of patents, wherever precedent solutions have been found that resolve a conflict between two of the elements the relevant cells in the matrix typically contain a sub-set of three or four Principles that have been applied most frequently in inventive solutions which resolve contradictions between those two elements.

The main objective of the contradiction matrix was to simplify the process of selecting the most appropriate Principle to resolve a specific contradiction. It was the core of all modifications of ARIZ till 1973. But in 1973, after introducing the concept of physical contradictions and creating SuField Analysis, Altshuller realized that the contradiction matrix was comparatively an inefficient tool and stopped working on it. Beginning ARIZ-71c contradiction matrix ceased to be the core of ARIZ and therefore was not a tool for solving inventive problems that Altshuller believed should be pursued. Physical contradictions and separation principles as well as SuField Analysis, etc became the core. Despite this, the 40 Principles has remained the most popular tool taught in introductory seminars and has consistently attracted the most attention amongst the tens of thousands of individuals who visit TRIZ-focused web sites in a typical month. Therefore, many of those who learn TRIZ or have attended seminars are taught quite wrongly that TRIZ is primarily composed of the 40 principles and contradiction matrix, the truth is ARIZ is the core methodology of TRIZ.

ARIZ is an algorithmic approach to finding inventive solutions by identifying and resolving contradictions. This includes the "System of Inventive Standards Solutions" which Altshuller used to replace the 40 principles and contradiction matrix, it comprises of Su-field modeling and the 76 Inventive Standards. A number of TRIZ-based computer programs have been developed whose purpose is to provide assistance to engineers and inventors in finding inventive solutions for technological problems. Some of these programs are also designed to apply another TRIZ methodology whose purpose is to reveal and forecast emergency situations and to anticipate circumstances which could result in undesirable outcomes.

One of the important branches of TRIZ is focused on analysing and predicting trends of evolution in the characteristics that existing solutions are likely to develop in successive generations of a system.

## Essentials

### Basic terms

- Ideal Final Result (IFR) - the ultimate idealistic solution of a problem when the desired result is achieved by itself;
  - Administrative Contradiction - contradiction between the needs and abilities;
  - Technical Contradiction - an inverse dependence between parameters/characteristics of a machine or technology;
  - Physical Contradiction - opposite/contradictory physical requirements to an object;
  - Separation principle - a method of resolving physical contradictions by separating contradictory requirements;
  - VePol or SuField - a minimal technical system consisting of two material objects (substances) and a "field". "Field" is the source of energy whereas one of the substances is "transmission" and the other one is the "tool";
  - FePol - a sort of VePol where "substances" are ferromagnetic objects;
  - Level of Invention;
  - Standard - a standard inventive solution of a higher level;
  - Law of Technical Systems Evolution;
  - ARIZ - Algorithm of Inventive Problems Solving, which combines various specialized methods of TRIZ into one universal tool;
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## Identifying a problem: contradictions

Altshuller believed that inventive problems stem from contradictions (one of the basic TRIZ concepts) between two or more elements, such as, "If we want more acceleration, we need a larger engine; but that will increase the cost of the car," that is, more of something desirable also brings more of something less desirable, or less of something else also desirable.

These are called Technical Contradictions by Altshuller. He also defined so-called physical or inherent contradictions: More of one thing and less of the same thing may both be desired in the same system. For instance, a higher temperature may be needed to melt a compound more rapidly, but a lower temperature may be needed to achieve a homogeneous mixture.

An "inventive situation" which challenges us to be inventive, might involve several such contradictions. Conventional solutions typically "trade" one contradictory parameter for another; no special inventiveness is needed for that. Rather, the inventor would develop a creative approach for resolving the contradiction, such as inventing an engine that produces more acceleration without increasing the cost of the engine.

## Inventive principles and the matrix of contradictions

Altshuller screened patents in order to find out what kind of contradictions were resolved or dissolved by the invention and the way this had been achieved. From this he developed a set of 40 inventive principles and later a Matrix of Contradictions. Rows of the matrix indicate the 39 system features that one typically wants to improve, such as speed, weight, accuracy of measurement and so on. Columns refer to typical undesired results. Each matrix cell points to principles that have been most frequently used in patents in order to resolve the contradiction.

For instance, Dolgashev mentions the following contradiction: Increasing accuracy of measurement of machined balls while avoiding the use of expensive microscopes and elaborate control equipment. The matrix cell in row "accuracy of measurement" and column "complexity of control" points to several principles, among them the Copying Principle, which states, "Use a simple and inexpensive optical copy with a suitable scale instead of an object that is complex, expensive, fragile or inconvenient to operate." From this general invention principle, the following idea might solve the problem: Taking a high-resolution image of the machined ball. A screen with a grid might provide the required measurement. As mentioned above, Altshuller abandoned this method of defining and solving "technical" contradictions in the mid 1980's and instead used Su-field modeling and the 76 inventive standards and a number of other tools included in the algorithm for solving inventive problems, ARIZ

## Laws of technical system evolution

Altshuller also studied the way technical systems have been developed and improved over time. From this, he discovered several trends (so called Laws of Technical Systems Evolution) that help engineers predict what the most likely improvements that can be made to a given product are. The most important of these laws involves the ideality of a system.

## Substance-field analysis

One more technique that is frequently used by inventors involves the analysis of substances, fields and other resources that are currently not being used and that can be found within the system or nearby. TRIZ uses non-standard definitions for substances and fields. Altshuller developed methods to analyze resources; several of his invention principles involve the use of different substances and fields that help resolve contradictions and increase ideality of a technical system. For instance, videotext systems used television signals to transfer data, by taking advantage of the small time segments between TV frames in the signals.

Su-Field Analysis (structural substance-field analysis) produces a structural model of the initial technological system, exposes its characteristics, and with the help of special laws, transforms the model of the problem. Through

this transformation the structure of the solution that eliminates the shortcomings of the initial problem is revealed. Su-Field Analysis is a special language of formulas with which it is possible to easily describe any technological system in terms of a specific (structural) model. A model produced in this manner is transformed according to special laws and regularities, thereby revealing the structural solution of the problem.

### **ARIZ - algorithm of inventive problems solving**

ARIZ (Russian acronym of Алгоритм решения изобретательских задач - АРИЗ) - Algorithm of Inventive Problems Solving - is a list of about 85 step-by-step procedures to solve complicated invention problems, where other tools of TRIZ alone (Su-field analysis, 40 inventive principles, etc.) are not sufficient.

Various TRIZ software (see Invention Machine, Ideation International...) is based on this algorithm (or an improved one).

Starting with an updated matrix of contradictions, semantic analysis, subcategories of inventive principles and lists of scientific effects, some new interactive applications are other attempts to simplify the problem formulation phase and the transition from a generic problem to a whole set of specific solutions.

(see External links for details)

### **Use of TRIZ methods in industry**

It has been reported that car companies Ford and Daimler-Chrysler, Johnson & Johnson, aeronautics companies Boeing, NASA, technology companies Hewlett Packard, Motorola, General Electric, Xerox, IBM, LG and Samsung, and Procter and Gamble and Kodak have used TRIZ methods in some projects.<sup>[5] [8] [9] [10]</sup>

### **Approaches which are modifications/derivatives of TRIZ**

1. SIT (Systematic Inventive Thinking)
2. ASIT (Advanced Systematic Inventive Thinking)
3. USIT (Unified Systematic Inventive Thinking)
4. JUSIT (Japanese version of Unified Systematic Inventive Thinking)
5. Southbeach notation

### **References**

- [1] Hua, Z.; Yang, J., Coulibaly, S. and Zhang, B. (2006). "Integration TRIZ with problem-solving tools: a literature review from 1995 to 2006" (<http://inderscience.metapress.com/app/home/content.asp>). *International Journal of Business Innovation and Research* **1** (1-2): 111–128. . Retrieved 2 October 2010.
- [2] Barry, Katie; Domb, Ellen and Slocum, Michael S.. "Triz - What is Triz" ([http://www.triz-journal.com/archives/what\\_is\\_triz/](http://www.triz-journal.com/archives/what_is_triz/)). *The Triz Journal*. Real Innovation Network. . Retrieved 2 October 2010.
- [3] Sheng, I. L. S.; Kok-Soo, T. (2010). "Eco-Efficient Product Design Using Theory of Inventive Problem Solving (TRIZ) Principles" (<http://scipub.org/fulltext/ajas/ajas76852-858.pdf>). *American Journal of Applied Sciences* **7** (6): 852–858. . Retrieved 30 September 2010.
- [4] "Генрих Саулович Альтшуллер (Genrich Saulovich Altshuller - short biography)" (<http://www.altshuller.ru/biography/>). [www.altshuller.ru](http://www.altshuller.ru). .
- [5] Wallace, Mark (June 29, 2000). "The science of invention" (<http://www.salon.com/tech/feature/2000/06/29/altshuller/index.html>). *Salon.com*. . Retrieved 3 October 2010.
- [6] Altshuller, G. S.; Shapiro, R. B. (1956). "О Психологии изобретательского творчества (On the psychology of inventive creation)" (<http://www.altshuller.ru/triz/triz0.asp?SESSID=dd5333ed09c8a91adaaa6acf8689073a>) (in Russian). *Вопросы Психологии (The Psychological Issues)* (6): 37–39. . Retrieved 4 October 2010.
- [7] Webb, Alan (August 2002). "TRIZ: an inventive approach to invention". *Manufacturing Engineer*: 171–177.
- [8] Jana, Reena (May 31, 2006). "The World According to TRIZ" ([http://www.businessweek.com/innovate/content/may2006/id20060531\\_965895.htm?chan=innovation\\_innovation+++design\\_innovation+and+design+lead](http://www.businessweek.com/innovate/content/may2006/id20060531_965895.htm?chan=innovation_innovation+++design_innovation+and+design+lead)). *Bloomberg Businessweek*. . Retrieved 3 October 2010.
- [9] Hamm, Steve (December 25, 2008). "Tech Innovations for Tough Times" ([http://www.businessweek.com/technology/content/dec2008/tc20081223\\_490913.htm](http://www.businessweek.com/technology/content/dec2008/tc20081223_490913.htm)). *Bloomberg Businessweek*. . Retrieved 3 October 2010.



[10] Lewis, Peter (September 19, 2005). "A Perpetual Crisis Machine" ([http://money.cnn.com/magazines/fortune/fortune\\_archive/2005/09/19/8272909/index.htm](http://money.cnn.com/magazines/fortune/fortune_archive/2005/09/19/8272909/index.htm)). *CNNMoney.com*. Retrieved 3 October 2010.

## Books on TRIZ by Altshuller

- Altshuller, Genrich (1973). *Innovation Algorithm*. Worcester, MA: Technical Innovation Center. ISBN 0-9640740-2-8.
- Altshuller, Genrich (1984). *Creativity as an Exact Science*. New York, NY: Gordon & Breach. ISBN 0-677-21230-5.
- Altshuller, Genrich (1994). *And Suddenly the Inventor Appeared*. translated by Lev Shulyak. Worcester, MA: Technical Innovation Center. ISBN 0-9640740-1-X.

## External links

- Official G.S. Altshuller foundation (<http://www.altshuller.ru/>)
- The Altshuller Institute for TRIZ Studies, Worcester, MA, USA (<http://www.aitriz.org>)
- The TRIZ Journal (<http://www.triz-journal.com>), main online journal for TRIZ practitioners; not peer-reviewed.
- Anti TRIZ-journal (<http://www3.sympatico.ca/karasik>) (A pro-TRIZ journal, in spite of its name. It is against TRIZ-Journal, not TRIZ.)

# Creativity techniques

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**Creativity techniques** are methods that encourage creative actions, whether in the arts or sciences. They focus on a variety of aspects of creativity, including techniques for idea generation and divergent thinking, methods of re-framing problems, changes in the affective environment and so on. They can be used as part of problem solving, artistic expression, or therapy. Some techniques require groups of two or more people while other techniques can be accomplished alone. These methods include word games, written exercises and different types of improvisation, or algorithms for approaching problems. Aleatory techniques exploiting randomness are also common.

## Aleatory techniques

Randomness, or aleatory, is the introduction of chance elements. Aleatory is commonly found in music, art, and literature, particularly in poetry. In film, Andy Voda made a movie in 1979 called "Chance Chants" which he produced by a flip of a coin, or roll of a dice. In music, John Cage, an avant-garde musician, composed music by superimposing star maps on blank sheet music, by rolling dice, and by preparing open ended scores that depended on the spontaneous decisions of the performers. (1) Other ways of practicing randomness include coin tossing, picking something out of a hat, or selecting random words from a dictionary.

In short, aleatory is a way to introduce new thoughts or ideas into a creative process.

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## Improvisation

Improvisation is a creative process which can be spoken, written, or composed without prior preparation.<sup>[1]</sup> Improvisation, also called extemporization, can lead to the discovery of new ways to act, new patterns of thought and practices, or new structures. Improvisation is used in the creation of music, theatre, and other various forms. Many artists also use improvisational techniques to help their creative flow.

Here are two significant methods:

- **Improvisational Theater** is a form of theater in which actors use improvisational acting techniques to perform spontaneously. Many “improv” techniques are taught in standard drama classes. The basic skills of listening, clarity, confidence, and performing instinctively and spontaneously are considered important skills for actors to develop.<sup>[2]</sup>
- **Free Improvisation** is real time composition. Musicians of all kinds “improv” music; this music is not limited to particular genre. Two contemporary musicians that use free improvisation are Anthony Braxton and Cecil Taylor. Through free improvisation, musicians can develop increased spontaneity and fluency.<sup>[3]</sup>

Each type of improvisation improves the thinking and acting skill of the actor, this is made by using no practise, a similar set of techniques is called *Alienation* since one of its many techniques uses actors that haven't rehearsed or even read the play, improvisation is an acting skill where actors make up a storyline, start and ending on the spot and actors have to try their best to keep in character.

## Problem Solving

In problem-solving contexts, the random word creativity technique is perhaps the simplest method. A person confronted with a problem is presented with a randomly generated word, in the hopes of a solution arising from any associations between the word and the problem. A random image, sound, or article can be used instead of a random word as a kind of creativity goad or provocation.<sup>[4] [5]</sup>

## References

- [1] <http://dictionary.reference.com/browse/improvisation>
- [2] [http://www.cognos.com/newsletter/decisions/st\\_070307\\_01.html](http://www.cognos.com/newsletter/decisions/st_070307_01.html)
- [3] <http://www.musilosophy.com/jazz-improvisation.htm>
- [4] [http://ideafly.com/archives/2003/05/09/more\\_on\\_idea\\_generation\\_tools\\_and\\_techniques.php](http://ideafly.com/archives/2003/05/09/more_on_idea_generation_tools_and_techniques.php)
- [5] <http://mitsloan.mit.edu/vc/Ideationpaper022805.pdf>

## External links

- Creativity Techniques - an A to Z ([http://www.mycoted.com/Category:Creativity\\_Techniques](http://www.mycoted.com/Category:Creativity_Techniques))

# Brainstorming

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**Brainstorming** is a group creativity technique designed to generate a large number of ideas for the solution of a problem. In 1953 the method was popularized by Alex Faickney Osborn in a book called *Applied Imagination*. Osborn proposed that groups could double their creative output with brainstorming.<sup>[1]</sup>

Although brainstorming has become a popular group technique, when applied in a traditional group setting, researchers have not found evidence of its effectiveness for enhancing either quantity or quality of ideas generated. Because of such problems as distraction, social loafing, evaluation apprehension, and production blocking, conventional brainstorming groups are little more effective than other types of groups, and they are actually less effective than individuals working independently.<sup>[2] [3] [4]</sup> In the Encyclopedia of Creativity, Tudor Rickards, in his entry on brainstorming, summarizes its controversies and indicates the dangers of conflating productivity in group work with quantity of ideas.<sup>[5]</sup>

Although traditional brainstorming does not increase the productivity of groups (as measured by the number of ideas generated), it may still provide benefits, such as boosting morale, enhancing work enjoyment, and improving team work. Thus, numerous attempts have been made to improve brainstorming or use more effective variations of the basic technique.

Professor Olivier Toubia of Columbia University has conducted extensive research in the field of idea generation and has concluded that incentives are extremely valuable within the brainstorming context.<sup>[6]</sup>

From these attempts to improve brainstorming, electronic brainstorming stands out. Mainly through anonymization and parallelization of input, electronic brainstorming enforces the ground rules of effective brainstorming and thereby eliminates most of the deleterious or inhibitive effects of group work.<sup>[7]</sup> The positive effects of electronic brainstorming become more pronounced with group size.<sup>[8]</sup>

## Ground Rules

There are four basic rules in brainstorming.<sup>[1]</sup> These are intended to reduce social inhibitions among group members, stimulate idea generation, and increase overall creativity of the group.

1. **Focus on quantity:** This rule is a means of enhancing divergent production, aiming to facilitate problem solving through the maxim *quantity breeds quality*. The assumption is that the greater the number of ideas generated, the greater the chance of producing a radical and effective solution.
  2. **Withhold criticism:** In brainstorming, criticism of ideas generated should be put 'on hold'. Instead, participants should focus on extending or adding to ideas, reserving criticism for a later 'critical stage' of the process. By suspending judgment, participants will feel free to generate unusual ideas.
  3. **Welcome unusual ideas:** To get a good and long list of ideas, unusual ideas are welcomed. They can be generated by looking from new perspectives and suspending assumptions. These new ways of thinking may provide better solutions.
  4. **Combine and improve ideas:** Good ideas may be combined to form a single better good idea, as suggested by the slogan "1+1=3". It is believed to stimulate the building of ideas by a process of association.
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## Method

### Set the problem

Before a brainstorming session, it is critical to define the problem. The problem must be clear, not too big, and captured in a specific question such as "What service for mobile phones is not available now, but needed?". If the problem is too big, the facilitator should break it into smaller components, each with its own question.

### Create a background memo

The background memo is the invitation and informational letter for the participants, containing the session name, problem, time, date, and place. The problem is described in the form of a question, and some example ideas are given. The memo is sent to the participants well in advance, so that they can think about the problem beforehand.

### Select participants

The facilitator composes the brainstorming panel, consisting of the participants and an idea collector. A group of 10 or fewer members is generally more productive. Many variations are possible but the following composition is suggested.

- Several core members of the project who have proved themselves.
- Several guests from outside the project, with affinity to the problem.
- One idea collector who records the suggested ideas.

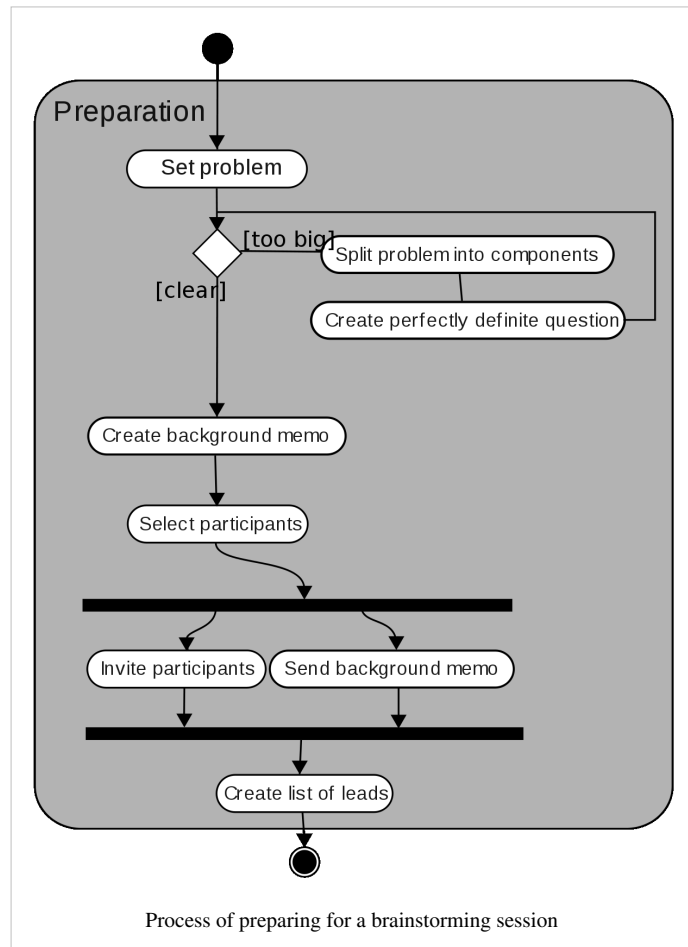
### Create a list of lead questions

During the brainstorm session the creativity may decrease. At this moment, the facilitator should stimulate creativity by suggesting a lead question to answer, such as *Can we combine these ideas?* or *How about looking from another perspective?*. It is best to prepare a list of such leads before the session begins.

### Session conduct

The facilitator leads the brainstorming session and ensures that ground rules are followed. The steps in a typical session are:

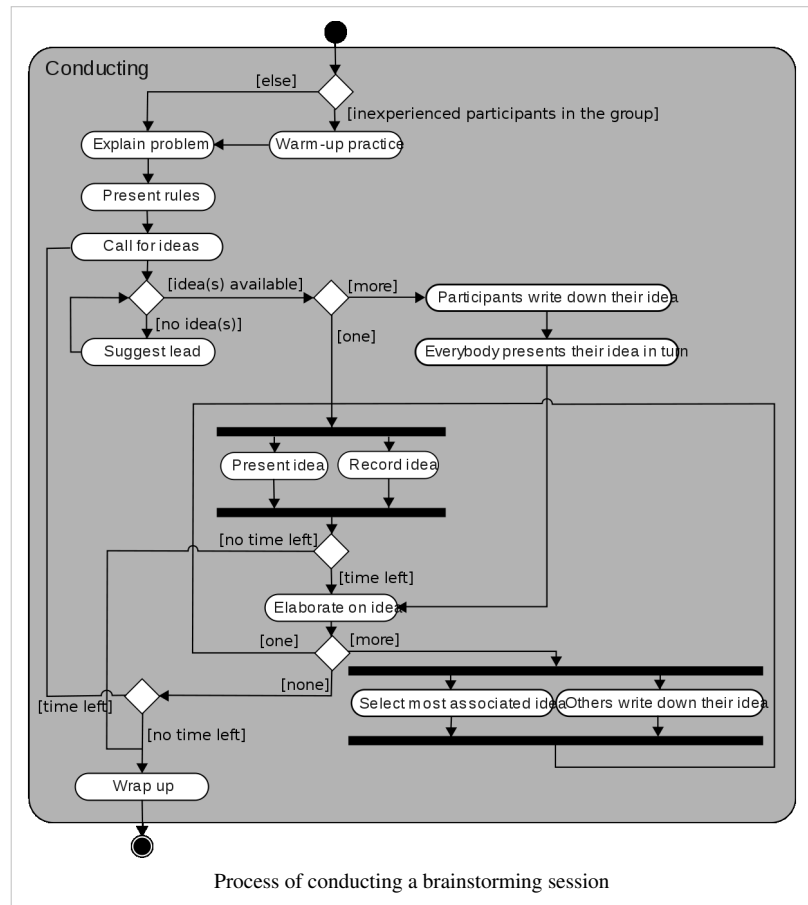
1. A warm-up session, to expose novice participants to the criticism-free environment. A simple problem is brainstormed, for example *What should be the CEO's retirement present?* or *What can be improved in Microsoft Windows?*.
2. The facilitator presents the problem and gives a further explanation if needed.
3. The facilitator asks the brainstorming group for their ideas.
4. If no ideas are forthcoming, the facilitator suggests a lead to encourage creativity.



5. All participants present their ideas, and the idea collector records them.
6. To ensure clarity, participants may elaborate on their ideas.
7. When time is up, the facilitator organizes the ideas based on the topic goal and encourages discussion.
8. Ideas are categorized.
9. The whole list is reviewed to ensure that everyone understands the ideas.
10. Duplicate ideas and obviously infeasible solutions are removed.
11. The facilitator thanks all participants and gives each a token of appreciation.

## The process

- Participants who have ideas but were unable to present them are encouraged to write down the ideas and present them later.
- The idea collector should number the ideas, so that the chairperson can use the number to encourage an idea generation goal, for example:  
*We have 44 ideas now, let's get it to 50!*
- The idea collector should repeat the idea in the words he or she has written verbatim, to confirm that it expresses the meaning intended by the originator.
- When many participants are having ideas, the one with the most associated idea should have priority. This is to encourage elaboration on previous ideas.
- During a brainstorming session, managers and other superiors may be discouraged from attending, since it may inhibit and reduce the effect of the four basic rules, especially the generation of unusual ideas.



## Evaluation

Brainstorming is not just about generating ideas for others to evaluate and select. Usually the group itself will, in its final stage, evaluate the ideas and select one as the solution to the problem proposed to the group.

- The solution should not require resources or skills the members of the group do not have or cannot acquire.
- If acquiring additional resources or skills is necessary, that needs to be the first part of the solution.
- There must be a way to measure progress and success.
- The steps to carry out the solution must be clear to all, and amenable to being assigned to the members so that each will have an important role.
- There must be a common decision making process to enable a coordinated effort to proceed, and to reassign tasks as the project unfolds.
- There should be evaluations at milestones to decide whether the group is on track toward a final solution.
- There should be incentives to participation so that participants maintain their efforts.

## Variations

### Nominal group technique

The nominal group technique is a type of brainstorming that encourages all participants to have an equal say in the process. It is also used to generate a ranked list of ideas.

Participants are asked to write their ideas anonymously. Then the moderator collects the ideas and each is voted on by the group. The vote can be as simple as a show of hands in favor of a given idea. This process is called distillation.

After distillation, the top ranked ideas may be sent back to the group or to subgroups for further brainstorming. For example, one group may work on the color required in a product. Another group may work on the size, and so forth. Each group will come back to the whole group for ranking the listed ideas. Sometimes ideas that were previously dropped may be brought forward again once the group has re-evaluated the ideas.

It is important that the facilitator be trained in this process before attempting to facilitate this technique. The group should be primed and encouraged to embrace the process. Like all team efforts, it may take a few practice sessions to train the team in the method before tackling the important ideas.

### Group passing technique

Each person in a circular group writes down one idea, and then passes the piece of paper to the next person in a clockwise direction, who adds some thoughts. This continues until everybody gets his or her original piece of paper back. By this time, it is likely that the group will have extensively elaborated on each idea.

The group may also create an "Idea Book" and post a distribution list or routing slip to the front of the book. On the first page is a description of the problem. The first person to receive the book lists his or her ideas and then routes the book to the next person on the distribution list. The second person can log new ideas or add to the ideas of the previous person. This continues until the distribution list is exhausted. A follow-up "read out" meeting is then held to discuss the ideas logged in the book. This technique takes longer, but it allows individuals time to think deeply about the problem.

### Team idea mapping method

This method of brainstorming works by the method of association. It may improve collaboration and increase the quantity of ideas, and is designed so that all attendees participate and no ideas are rejected.

The process begins with a well-defined topic. Each participant brainstorms individually, then all the ideas are merged onto one large idea map. During this consolidation phase, participants may discover a common understanding of the issues as they share the meanings behind their ideas. During this sharing, new ideas may arise by the association, and they are added to the map as well. Once all the ideas are captured, the group can prioritize and/or take action.

### Electronic brainstorming

Electronic brainstorming is a computerized version of the manual brainstorming technique. It is typically supported by an electronic meeting system (EMS) but simpler forms can also be done via email and may be browser based, or use peer-to-peer software.

With an electronic meeting system, participants share a list of ideas over the Internet. Ideas are entered independently. Contributions become immediately visible to all and are typically anonymized to encourage openness and reduce personal prejudice. Modern EMS also support asynchronous brainstorming sessions over extended periods of time as well as typical follow-up activities in the creative-problem-solving process such as categorization of ideas, elimination of duplicates, assessment and discussion of prioritized or controversial ideas.

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Electronic brainstorming eliminates many of the problems of standard brainstorming, production blocking and evaluation apprehension. An additional advantage of this method is that all ideas can be archived electronically in their original form, and then retrieved later for further thought and discussion. Electronic brainstorming also enables much larger groups to brainstorm on a topic than would normally be productive in a traditional brainstorming session.<sup>[9]</sup>

Some web based brainstorming techniques allow contributors to post their comments anonymously through the use of avatars. This technique also allows users to log on over an extended time period, typically one or two weeks, to allow participants some "soak time" before posting their ideas and feedback. This technique has been used particularly in the field of new product development, but can be applied in any number of areas where collecting and evaluating ideas would be useful.

### **Directed brainstorming**

Directed brainstorming is a variation of electronic brainstorming (described above). It can be done manually or with computers. Directed brainstorming works when the solution space (that is, the criteria for evaluating a good idea) is known prior to the session. If known, that criteria can be used to intentionally constrain the ideation process.

In directed brainstorming, each participant is given one sheet of paper (or electronic form) and told the brainstorming question. They are asked to produce one response and stop, then all of the papers (or forms) are randomly swapped among the participants. The participants are asked to look at the idea they received and to create a new idea that improves on that idea based on the initial criteria. The forms are then swapped again and respondents are asked to improve upon the ideas, and the process is repeated for three or more rounds.

In the laboratory, directed brainstorming has been found to almost triple the productivity of groups over electronic brainstorming.<sup>[10]</sup>

### **Individual brainstorming**

"Individual Brainstorming" is the use of brainstorming on a solitary basis. It typically includes such techniques as free writing, free speaking, word association, and drawing a mind map, which is a visual note taking technique in which people diagram their thoughts. Individual brainstorming is a useful method in creative writing and has been shown to be superior to traditional group brainstorming.<sup>[11]</sup>

### **Question Brainstorming**

This process involves brainstorming the *questions*, rather than trying to come up with immediate answers and short term solutions. This technique stimulates creativity and promotes everyone's participation because no one has to come up with answers. The answers to the questions form the framework for constructing future action plans. Once the list of questions is set, it may be necessary to prioritize them to reach to the best solution in an orderly way.<sup>[12]</sup> Another of the problems for brainstorming can be to find the best evaluation methods for a problem.

Brainstorming all the questions has also been called *questorming*.<sup>[13]</sup>

### **Conclusion**

Brainstorming is a popular method of group interaction in both educational and business settings. Although it does not provide a measurable advantage in creative output, conventional brainstorming is an enjoyable exercise that is typically well received by participants. Electronic brainstorming effectively overcomes barriers inherent in group work like production blocking mainly through anonymization and parallelization of contributions.<sup>[14]</sup> Other variations of brainstorming that do not require an electronic system may also prove superior to the original technique. How well these methods work, and whether or not they should be classified as brainstorming, are questions that require further research.

## Controversy over term

Some governmental organisations (The Welsh Development Agency and the Department of Enterprise, Trade and Investment in Belfast) have reached the conclusion that the term 'brainstorming' is offensive to people with epilepsy<sup>[15]</sup> (see political correctness) and have suggested the alternative "thought-showers". However, research by the National Society for Epilepsy found of those affected by epilepsy questioned, 93% considered the term inoffensive. A specific comment states that changes need not be made since that could promote an undesirable image of epileptics being easily offended<sup>[15]</sup>.

## References

- [1] Osborn, A.F. (1963) *Applied imagination: Principles and procedures of creative problem solving* (Third Revised Edition). New York, NY: Charles Scribner's Son.
- [2] Nijstad, B. A., Stroebe, W. Lodewijkx, H. F. M. (2003). Production blocking and idea generation: Does blocking interfere with cognitive processes? *Journal of Experimental Social Psychology*, 39, 531-548.
- [3] Diehl, M., & Stroebe, W. (1991). Productivity loss in idea-generating groups: tracking down the blocking effect. *Journal of Personality and Social Psychology*, 61, 392-403.
- [4] Mullen, B., Johnson, C., & Salas, E. (1991). Productivity loss in brainstorming groups: a meta-analytic integration. *Basic and Applied Social Psychology*, 12, 3-23.
- [5] Rickards, T., (1999) Brainstorming, M Runco & S Pritzker, Eds, Encyclopedia of Creativity, San Diego: Academic Press Vol 1 219-228.
- [6] Toubia, Olivier, "Idea Generation, Creativity, and Incentives," *Marketing Science* (2006)
- [7] Nunamaker, J., Dennis, A. R., Valacich, J. S., Vogel, D. R. and George, J. F. (1991), "Electronic Meeting Systems to Support Group Work," *Communications of the ACM*, Vol. 34, No. 7, pp. 40-61
- [8] Dennis, A. R. and Valacich, J. S. (1993), "Computer Brainstorms: More Heads are Better than One," *Journal of Applied Psychology*, Vol. 78, No. 4, pp. 531-537.
- [9] Gallupe, R. B., Dennis, A. R., Cooper, W. H., Valacich, J. S., Bastianutti, L. M. and Nunamaker, J. F. (1992), "Electronic Brainstorming and Group Size," *Academy of Management Journal*, Vol. 35, No. 2, pp. 350-369.
- [10] Santanen, E., Briggs, R. O., & de Vreede, G-J. (2004). Causal Relationships in Creative Problem Solving: Comparing Facilitation Interventions for Ideation. *Journal of Management Information Systems*, 20(4), 167-198.
- [11] Furnham, A., & Yazdanpanahi, T. (1995). Personality differences and group versus individual brainstorming. *Personality and Individual Differences*, 19, 73-80.
- [12] Ludy, Perry J. *Profit Building: Cutting Costs Without Cutting People*. San Francisco: Berret-Koehler, Inc, 2000. Print.
- [13] Questorming: An Outline of the Method (<http://pynthan.com/vri/questorm.htm>), Jon Roland, 1985
- [14] McFadzean, E. S. (1997), "Improving Group Productivity with Group Support Systems and Creative Problem Solving Techniques", *Creativity and Innovation Management*, Vol. 6, No. 4, pp. 218-225.
- [15] (<http://www.epilepsy.org.uk/node/1078>) Epilepsy Action, 2005

## External links

- Public online Brainstorming (<http://www.brainstorming.com>)
- Brainstorming Approach (University of North Carolina) (<http://www.unc.edu/depts/wcweb/handouts/brainstorming.html>)
- Brain Storm: A wiki-style brainstorming tool (<http://www.brainstormproject.net>)
- Brainstorming magazine (<http://www.brainstorming.ba>)



# Improvisation

**Improvisation** is the practice of acting, singing, talking and reacting, of making and creating, in the moment and in response to the stimulus of one's immediate environment and inner feelings. This can result in the invention of new thought patterns, new practices, new structures or symbols, and/or new ways to act. This *invention cycle* occurs most effectively when the practitioner has a thorough *intuitive* and *technical* understanding of the necessary skills and concerns within the improvised domain. Improvisation can be thought of as an "on the spot" or "off the cuff" spontaneous activity.

The skills of improvisation can apply to many different abilities or forms of communication and expression across all artistic, scientific, physical, cognitive, academic, and non-academic disciplines. For example, improvisation can make a significant contribution in music, dance, cooking, presenting a speech, sales, personal or romantic relationships, sports, flower arranging, martial arts, psychotherapy, and much more. Techniques of improvisation are widely trained in the entertainment arts; for example, music, theatre and dance. To "*extemporize*" or "*ad lib*" is basically the same as improvising. Colloquial terms such as "let's play it by ear," "take it as it comes," and "make it up as we go along" are all used to describe "improvisation."

The simple act of speaking requires a good deal of improvisation because the mind is addressing its own thought and creating its unrehearsed delivery in words, sounds and gestures, forming unpredictable statements that feed back into the thought process (the performer as listener), creating an enriched process that is not unlike instantaneous composition [with a given set or repertoire of elements].<sup>[1]</sup>

Where the improvisation is intended to solve a problem on a temporary basis, the 'proper' solution being unavailable at the time, it may be known as a **stop-gap**. This particularly applies to engineering improvisations.

## Music

Improvisation is usually defined as composing music while singing or playing an instrument at the same time. In other words, the art of improvisation can be understood as composing music "on the fly". This requires great skill and knowledge, and is a very important aspect of music in general. Musical improvisers often understand the idiom of one or more musical styles — such as blues, rock, folk, jazz — and work within the idiom and music-theory of the certain style to express ideas with creativity and originality. Improvisation can take place as a solo performance, or interdependently in ensemble with other players. When done well, it often elicits gratifying emotional responses from the audience. Very few musicians have ever dared to offer fully improvised concerts such as the famous improvised piano recitals by classical composers/pianists like Franz Liszt. The origins of Liszt's improvisation in an earlier tradition of playing variations on a theme were mastered and epitomized by Bach, Mozart and Beethoven. However, some have managed some attempts similar to these precedents, one of the most successful of these is Keith Jarrett, a jazz pianist and multi-instrumentalist who has performed many completely improvised concerts all over the world. In the same creative aesthetic as such named masters, including the late innovator and guitar master Derek Bailey, comes a new breed of improvising musician. Pioneers like cellist Eugene Friesen have brought improvisation to traditionally classical instruments. A few pianists have given modern recitals of improvisation in the baroque style, which may be less intimidating because of its stricter development and range of modulation and yet, on the other hand, more daunting because of its polyphony. One of the masters in the style of baroque improvisation was Glenn Gould. There have also been a few other exceptional improvised solo piano concerts in Stuttgart, Southern Germany in the 1990s. There are also full bands who play 100% live improvisation music at their



ComedySportz Austin performing a shortform game based on direction from the audience with the help of Red Dirt Improv; in this case spoofing a hard rock band performing a song made up on the stage

concerts, making up the standards, patterns, rhythms, melodies, harmonies, lyrics, solos, etc. at the top of their heads. Examples are bands like Xlovers 'Beyond Jazz' 2003 Concerts <sup>[2]</sup>, and the band 42winA2, Holland 2010.<sup>[3]</sup> In the realm of silent film music, there are also a small number of musicians whose work has been recognized as exceptional by critics, scholars and audiences alike: Neil Brand, Guenter A. Buchwald, Philip Carli, Stephen Horne, Donald Sosin, John Sweeney, and Gabriel Thibaudeau, all performers at the annual conference on silent film in Pordenone, Italy, "Le Giornate del Cinema Muto." Their performances have to match the style and pacing of the films they accompany, often at first sight, and demand a knowledge of a wide range of musical styles, as well as the stamina to play for films which occasionally run over three hours in length without a pause. It is used in drama to act out characters.

## Dance

Dance improvisation as a choreographic tool: Improvisation is used as a choreographic tool in dance composition. Experimenting with the concepts of shape, space, time, and energy while moving without inhibition or cognitive thinking can create unique and innovative movement designs, spatial configuration, dynamics, and unpredictable rhythms. Improvisation without inhibition allows the choreographer to connect to their deepest creative self, which in turn clears the way for pure invention.

Contact improvisation: a form developed in 1973, that is now practiced around the world. Contact improvisation originated from the movement studies of Steve Paxton in the 1970s and developed through the continued exploration of the Judson Dance Theater. It is a dance form based on sharing weight, partnering, playing with weight and unpredictable outcomes.

## Sculpture

Sculpture often relies on the enlargement of a small model or maquette to create the final work in a chosen material. Where the material is *plastic* such as clay, a working structure or armature often needs to be built to allow the pre-determined design to be realized. Alan Thornhill's method for working with clay abandons the maquette, seeing it as *ultimately deadening to creativity*.<sup>[4]</sup> Without the restrictions of the armature, a clay matrix of elements allows that when recognisable forms start to emerge, they can be essentially disregarded by turning the work, allowing for infinite possibility and the chance for the unforeseen to emerge more powerfully at a later stage.

Moving from *adding and taking away* to purely reductive working, the architectural considerations of turning the work are eased considerably but continued removal of material through the rejection of forms deemed *too obvious* can mean one ends up with nothing. Former pupil Jon Edgar uses Thornhill's method as a creative extension to direct carving in stone and wood.

## Film

The director Mike Leigh uses lengthy improvisations developed over a period of weeks to build characters and story lines for his films. He starts with some sketch ideas of how he thinks things might develop but does not reveal all his intentions with the cast who discover their fate and act out their responses as their destinies are gradually revealed, including significant aspects of their lives which will not subsequently be shown onscreen. The final filming draws on dialogue and actions that have been recorded during the improvisation period.

## Comedy

Improvisational comedy is a theater art performed throughout the world and has had on-again, off-again status throughout history.

Some of the more famous improv theaters and training centers in the world include: i.O. (formerly ImprovOlympic) in Chicago and Los Angeles, The Second City in Chicago and Toronto, The Players Workshop in Chicago, National Comedy Theatre in San Diego, New York and Phoenix, Upright Citizens Brigade in New York City, the Groundlings, BATS Improv in San Francisco, Wing-It Productions in Seattle, Philly Improv Theater in Philadelphia, The Hideout Theatre and The ColdTowne Theater in Austin, Dudley Riggs BraveNew Workshop in Minneapolis, ComedySportz in Milwaukee, The Improv Effect in Jacksonville, FL, The ImprovTrick in Saint Louis, Missouri, Washington Improv Theater in Washington D.C., and Theatresports in Calgary, Canada.

There are also many well known university improv teams, including The University of Pennsylvania's Without a Net, Duke University Improv, the Titanic Players, and Theatre Strike Force at the University of Florida.

Notable pioneers in the field of improvisation, comedic or otherwise, include Viola Spolin, Paul Sills, David Shepherd, Del Close, Josephine Forsberg, Stan Wells, Martin de Maat, and Keith Johnstone. Notable performers include: Paul Merton, Stephen Colbert, Steve Carell, Bill Murray, Harold Ramis, Robert Townsend, Colin Mochrie, Ryan Stiles, Ross Noble, Wayne Brady, Robin Williams, Jonathan Winters, Bill Chott, Eddie Izzard and Gil Christner.

## Poetry

Traditional epic poetry included improvisation moments where the reciter flattered the audience (especially the authorities) or to substitute a forgotten passage. There are also societies that value improvised poetry as a genre, often as a debate or "poetic joust", where improvisators compete for public approval. Some of these impromptu poems are later recorded in paper or transmitted orally.

Usually wit is as valued as conformity to poetical form.

Some of these forms also include humour. But Michel Ducom established himself within Bordeaux poetical improvisation movement in the 1990s but has since composed and performed with a wide range of poets working in diverse poetical areas (Bernat Manciet, Serge Pey, Méryl Marchetti...). The emergence of poetical improvisation, like previous developments in French poetry, was largely tied to the free jazz experience.

## Television

In the 1990s, a TV show called *Whose Line Is It Anyway?* popularized shortform comedic improvisation. The original version was British, but it was later revived and popularized in the United States with Drew Carey as a host. More recently, television shows such as HBO's *Curb Your Enthusiasm* (starring *Seinfeld* co-creator Larry David) and Bravo series *Significant Others (2004 TV series)* have used improvisation to create longer-form programs with more dramatic flavor. Other long-form partially improvised programs of note are *Sons & Daughters* (U.S. TV series), *10 Items or Less* (TV series), *Dog Bites Man*, *Halfway Home* (TV series), *Reno 911!*, *Free Ride* (TV series), *Campus Ladies*, and *Players* (2010 TV series)

In Canada, the Global Television soap opera *Train 48*, based on the Australian series *Going Home*, uses a form of structured improvisation, in which actors improvise dialog from written plot outlines. Australia's *Thank God You're Here* is a game show where celebrities are put into scenes they know nothing about and have to improvise.

## Engineering

Improvisation in engineering is to solve a problem with the tools and materials immediately at hand. A classic example of such improvisation was the re-engineering of carbon dioxide scrubbers with the materials on hand during the Apollo 13 space mission.

Engineering improvisations may be needed because of emergencies, embargo, obsolescence of a product and the loss of manufacturer support, or perhaps just a lack of funding appropriate for a better solution.

The popular television program MacGyver used as its gimmick a hero who could solve almost any problem with jury rigged devices from everyday materials, a Swiss Army knife and some duct tape.

## Improvised weapons

Improvised weapons are often used by guerrillas, insurgents and criminals as conventional weapons may be unavailable. Such weapons vary in sophistication from simple sharpened sticks, to petrol bombs and home made napalm, to IEDs and make shift bomber aircraft.

## General references

- Abbot, John. 2009. *Improvisation in Rehearsal*. Nick Hern Books. ISBN 978-1854595232
- Abbot, John. 2007. *The Improvisation Book*. Nick Hern Books. ISBN 978-1854599612
- Johnston, Chris. 2006. *The Improvisation Game: Discovering the Secrets of Spontaneous Performance*. Nick Hern Books. ISBN 978-1854596680
- Nachmanovitch, Stephen. 1990. *Free Play: Improvisation in Life and Art*. Penguin/Tarcher. ISBN 0874775787 (cloth); ISBN 0874776317 (pbk)

## References

- [1] (*The Speech Chain: The Physics and Biology of Spoken Language (Paperback)*," Peter B. Denes (Author), Elliot N. Pinson (Author). 1966. Worth Publishers; Second Edition (February 15, 1993))
- [2] Xlovers on the Web – 100% improvisation concerts (<http://www.myspace.com/xloverslive>)
- [3] 42wina2 on the Web – 100% improvisation concerts (<http://www.myspace.com/42wina2>)
- [4] Film: Spirit in Mass – Journey into Sculpture (2007) ([http://www.alanthornhill.co.uk/Spirit in Mass film.htm](http://www.alanthornhill.co.uk/Spirit%20in%20Mass%20film.htm))

## External links

- Improvisation ([http://www.dmoz.org/Arts/Performing\\_Arts/Theatre/Improvisational/](http://www.dmoz.org/Arts/Performing_Arts/Theatre/Improvisational/)) at the Open Directory Project
- Critical studies in improvisation (<http://www.criticalimprov.com/public/csi/index.html>)

# Creative problem solving

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**Creative problem solving** is the mental process of creating a solution to a problem. It is a special form of problem solving in which the solution is independently created rather than learned with assistance.

Creative problem solving always involves creativity. However, creativity often does not involve creative problem solving, especially in fields such as music, poetry, and art. Creativity requires newness or novelty as a characteristic of what is created, but creativity does not necessarily imply that what is created has value or is appreciated by other people.

To qualify as creative problem solving the solution must either have value, clearly solve the stated problem, or be appreciated by someone for whom the situation improves.<sup>[1]</sup>

The situation prior to the solution does not need to be labeled as a problem. Alternate labels include a challenge, an opportunity, or a situation in which there is room for improvement.<sup>[1]</sup>

Solving school-assigned homework problems does not usually involve creative problem solving because such problems typically have well-known solutions.<sup>[1]</sup>

If a created solution becomes widely used, the solution becomes an innovation and the word innovation also refers to the process of creating that innovation. A widespread and long-lived innovation typically becomes a new tradition. "All innovations [begin] as creative solutions, but not all creative solutions become innovations."<sup>[1]</sup> Some innovations also qualify as inventions.<sup>[1]</sup>

Inventing is a special kind of creative problem solving in which the created solution qualifies as an invention because it is a useful new object, substance, process, software, or other kind of marketable entity.<sup>[1]</sup>

## Techniques and tools

Many of the techniques and tools for creating an effective solution to a problem are described in creativity techniques and problem solving.

Creative-problem-solving techniques can be categorized as follows:

- Creativity techniques designed to shift a person's mental state into one that fosters creativity. These techniques are described in creativity techniques. One such popular technique is to take a break and relax or sleep after intensively trying to think of a solution.
- Creativity techniques designed to reframe the problem. For example, reconsidering one's goals by asking "What am I really trying to accomplish?" can lead to useful insights.
- Creativity techniques designed to increase the quantity of fresh ideas. This approach is based on the belief that a larger number of ideas increase the chances that one of them has value. Some of these techniques involve randomly selecting an idea (such as choosing a word from a list), thinking about similarities with the undesired situation, and hopefully inspiring a related idea that leads to a solution. Such techniques are described in creativity techniques.
- Creative-problem-solving techniques designed to efficiently lead to a fresh perspective that causes a solution to become obvious. This category is useful for solving especially challenging problems.<sup>[1]</sup> Some of these techniques involve identifying independent dimensions that differentiate (or separate) closely associated concepts.<sup>[1]</sup> Such techniques can overcome the mind's instinctive tendency to use "oversimplified associative thinking" in which two related concepts are so closely associated that their differences, and independence from one another, are overlooked.<sup>[1]</sup>

The following formalized and well-known methods and processes combine various creativity and creative-problem-solving techniques:

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- TRIZ, which is also known as Theory of Inventive Problem Solving (TIPS), was developed by Genrich Altshuller and his colleagues based on examining more than 200,000 patents. This method is designed to foster the creation and development of patentable inventions, but is also useful for creating non-product solutions.
- Mind mapping is a creativity technique that both reframes the situation and fosters creativity.
- Brainstorming is a group activity designed to increase the quantity of fresh ideas. Getting other people involved can help increase knowledge and understanding of the problem and help participants reframe the problem.
- Edward de Bono has published numerous books that promote an approach to creative problem solving and creative thinking called lateral thinking.
- The Creative Problem Solving Process (CPS) is a six-step method developed by Alex Osborn and Sid Parnes that alternates convergent and divergent thinking phases.

A frequent approach to teaching creative problem solving is to teach critical thinking in addition to creative thinking, but the effectiveness of this approach is not proven. As an alternative to separating critical and creative thinking, some creative-problem-solving techniques focus on either reducing an idea's disadvantages or extracting a flawed idea's significant advantages and incorporating those advantages into a different idea.<sup>[1]</sup>

Creative-problem-solving tools typically consist of software or manipulatable objects (such as cards) that facilitate specific creative-problem-solving techniques. Electronic meeting systems provide a range of interactive tools for creative-problem-solving by groups over the Internet.

## References

- [1] Richard Fobes, *The Creative Problem Solver's Toolbox: A Complete Course in the Art of Creating Solutions to Problems of Any Kind* (1993) ISBN 0-96-322210-4

## Further reading

- Alex Osborn, *Applied Imagination: Principles and Procedures of Creative Problem Solving*, Creative Education Foundation Press, 1953/2001, ISBN 0-930222-73-3
- Edward de Bono, *Lateral Thinking : Creativity Step by Step*, Harper & Row, 1973, trade paperback, 300 pages, ISBN 0-06-090325-2
- Altshuller, Henry. 1994. *The Art of Inventing (And Suddenly the Inventor Appeared)*. Translated by Lev Shulyak. Worcester, MA: Technical Innovation Center. ISBN 0-9640740-1-X
- McFadzean, E.S. (1996), *New Ways of Thinking: An Evaluation of K-Groupware and Creative Problem Solving*, Doctoral Dissertation, Brunel University, Uxbridge, Middlesex.
- McFadzean, E.S. (1997), "Improving Group Productivity with Group Support Systems and Creative Problem Solving Techniques", *Creativity and Innovation Management*, Vol. 6, No. 4, pp. 218-225.

## External links

- Destination ImagiNation Inc. (<http://www.idodi.org>) A global, non-profit program dedicated to teaching teamwork and creative problem solving to kids of all ages.
- Odyssey of the Mind (<http://www.odysseyofthemind.com>) An international creative problem-solving program for students K-college.
- Creative Education Foundation (<http://www.creativeeducationfoundation.org>)
- Creative Problem Solving Institute (<http://www.cpsiconference.com>)
- International Center for Studies in Creativity (<http://www.buffalostate.edu/centers/creativity/>)
- Includes a list of techniques for creative problem solving (<http://www.mycoted.com/index.htm>)
- Problemistics: the art and craft of Problem Dealing (<http://www.problemistics.org/courseware/front.page.html>) A courseware on Problem Finding and Problem Solving

- Creative-problem-solving tips (<http://www.solutionscreative.com/cpstips.html>) Tips that originally appeared in the American Creativity Association's newsletter.
- Sustainable Earth Solutions (<http://www.sustainableearthssolutions.com/>) Environmental Youth Leadership Organization using the process

## Intuition (knowledge)

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The term **intuition** is used to describe "thoughts and preferences that come to mind quickly and without much reflection".<sup>[1]</sup> "The word 'intuition' comes from the Latin word 'intueri', which is often roughly translated as meaning 'to look inside' or 'to contemplate'."<sup>[2]</sup> Intuition provides us with beliefs that we cannot necessarily justify. For this reason, it has been the subject of study in psychology, as well as a topic of interest in the supernatural. The "right brain" is popularly associated with intuitive processes such as aesthetic abilities.<sup>[3]</sup> <sup>[4]</sup> <sup>[5]</sup> Some scientists have contended that intuition is associated with innovation in scientific discovery.<sup>[6]</sup> Intuition is also a common subject of New Age writings.<sup>[7]</sup>

### In psychology and personality assessment

In Carl Jung's theory of the ego, described in 1921 in *Psychological Types*, intuition was an "irrational function", opposed most directly by sensation, and opposed less strongly by the "rational functions" of thinking and feeling. Jung defined intuition as "perception via the unconscious": using sense-perception only as a starting point, to bring forth ideas, images, possibilities, ways out of a blocked situation, by a process that is mostly unconscious.

Jung said that a person in whom intuition was dominant, an "intuitive type", acted not on the basis of rational judgment but on sheer intensity of perception. An extraverted intuitive type, "the natural champion of all minorities with a future", orients to new and promising but unproven possibilities, often leaving to chase after a new possibility before old ventures have borne fruit, oblivious to his or her own welfare in the constant pursuit of change. An introverted intuitive type orients by images from the unconscious, ever exploring the psychic world of the archetypes, seeking to perceive the meaning of events, but often having no interest in playing a role in those events and not seeing any connection between the contents of the psychic world and him- or herself. Jung thought that extraverted intuitive types were likely entrepreneurs, speculators, cultural revolutionaries, often undone by a desire to escape every situation before it becomes settled and constraining—even repeatedly leaving lovers for the sake of new romantic possibilities. His introverted intuitive types were likely mystics, prophets, or cranks, struggling with a tension between protecting their visions from influence by others and making their ideas comprehensible and reasonably persuasive to others—a necessity for those visions to bear real fruit.<sup>[8]</sup>

The Myers-Briggs Type Indicator (MBTI), first published in 1944, attempted to provide an empirical method of identifying a person's dominant ego function, in terms of Carl Jung's theory. Tabulations of MBTI results showed that about one fourth of the United States population favor intuition over sensing. Such people are highly overrepresented in some careers: for example, about 60% of college professors, and two thirds of psychological counselors, favor intuition.<sup>[9]</sup> Whether an intuitive ego function really exists, or MBTI results really tell whether a person's dominant function is intuition, is highly doubtful, and is rejected by most contemporary psychological research. Even so, the MBTI is still widely used in career and marital counseling.

In more-recent psychology, intuition can encompass the ability to know valid solutions to problems and decision making. For example, the recognition primed decision (RPD) model explains how people can make relatively fast decisions without having to compare options. Gary Klein found that under time pressure, high stakes, and changing parameters, experts used their base of experience to identify similar situations and intuitively choose feasible solutions. Thus, the RPD model is a blend of intuition and analysis. The intuition is the pattern-matching process that quickly suggests feasible courses of action. The analysis is the mental simulation, a conscious and deliberate review

of the courses of action.<sup>[10]</sup>

According to the renowned neuropsychologist and neurobiologist Roger Wolcott Sperry though, intuition is a right-brain activity while factual and mathematical analysis is a left-brain activity.<sup>[11]</sup>

The reliability of one's intuition depends greatly on past knowledge and occurrences in a specific area. For example, someone who has had more experiences with children will tend to have a better instinct or intuition about what they should do in certain situations with them. This is not to say that one with a great amount of experience is always going to have an accurate intuition (because some can be biased); however, the chances of it being more reliable are definitely amplified.<sup>[12]</sup>

It has been asserted that Jung's analytical psychological theory of synchronicity is equal to intellectual intuition.<sup>[13]</sup>

## Intuition and spirituality

Intuition is commonly discussed in writings of spiritual thought. Contextually, there is often an idea of a transcendent and more qualitative mind of one's spirit towards which a person strives, or towards which consciousness evolves. Typically, intuition is regarded as a conscious commonality between earthly knowledge and the higher spiritual knowledge<sup>[14]</sup> and appears as flashes of illumination.<sup>[15]</sup> It is asserted that by definition intuition cannot be judged by logical reasoning.<sup>[16]</sup>

Thomas Merton discussed variations of intuition in a series of essays. In describing aesthetic intuition he asserted that the artist has a subjective identification with an object that is both heightened and intensified and thereby "sees" the object's spiritual reality.<sup>[17]</sup> In discussing Zen meditation he asserted that a direct intuition is derived through a "struggle against conceptual knowledge." An end result is "the existent knows existence, or 'isness,' while completely losing sight of itself as a 'knowing subject.'"<sup>[18]</sup>

Rudolf Steiner postulated that intuition is the third of three stages of higher knowledge, coming after imagination and inspiration, and is characterized by a state of immediate and complete experience of, or even union with, the object of knowledge without loss of the subject's individual ego.<sup>[19]</sup>

The high value of intuition in the Sufi schemata is related by El Sayeed Idries Shah el-Hashimi el-Naqshbandi, Grand Sheikh of the Dervish Orders.<sup>[20]</sup>

## Studies and claims

Dismissing the notion that intuitive impulses arise supernaturally, one is left to assume they originate with the five innate human senses. Remnants of perception, such as a movement occurring out of the "corner of your eye" or subtle sound that would normally be ignored as background noise, could occur simultaneously. While these events could be filtered as irrelevant by the mind, their coincidental synchronicity could lead to sudden assumptions about one's surroundings, such as the feeling of being watched or followed.

Intuitive abilities were quantitatively tested at Yale University in the 1970s. While studying nonverbal communication, researchers noted that some subjects were able to read nonverbal facial cues before reinforcement occurred.<sup>[21]</sup> In employing a similar design, they noted that highly intuitive subjects made decisions quickly but could not identify their rationale. Their level of accuracy, however, did not differ from that of nonintuitive subjects.<sup>[22]</sup>

Law enforcement officers often claim to observe suspects and immediately "know" that they possess a weapon or illicit narcotic substances. Often unable to articulate why they reacted or what prompted them at the time of the event, they sometimes retrospectively can plot their actions based upon what had been clear and present danger signals. Such examples liken intuition to "gut feelings" and when viable illustrate preconscious activity.<sup>[23]</sup>



## Various definitions

Intuition is a combination of historical (empirical) data, deep and heightened observation and an ability to cut through the thickness of surface reality. Intuition is like a slow motion machine that captures data instantaneously and hits you like a ton of bricks. Intuition is a knowing, a sensing that is beyond the conscious understanding — a gut feeling. Intuition is not pseudo-science.

– Abella Arthur

Intuition (is) perception via the unconscious

– Carl Gustav Jung

INTUITION may be defined as understanding or knowing without conscious recourse to thought, observation or reason. Some see this unmediated process as somehow mystical while others describe intuition as being a response to unconscious cues or implicitly apprehended prior learning.

– Dr. Jason Gallate & Ms Shannan Keen BA<sup>[24]</sup>

## Honor

Intuition Peak on Livingston Island in the South Shetland Islands, Antarctica is named in appreciation of the role of scientific intuition for the advancement of human knowledge.<sup>[25]</sup>

## Notes and references

- [1] Kahneman D. (2003) A Perspective on Judgment and Choice. *American Psychologist*, 58(9), 697-720.
- [2] Carlin Flora. "Gut Almighty". *Psychology Today*. Vol 40. Issue 3:68-75,2007.
- [3] Converting Words into Pictures--Reading Comprehension Guide--Academic Support (<http://academic.cuesta.edu/acasupp/AS/312.HTM>).
- [4] Left/Right Processing. (<http://frank.mtsu.edu/~studskl/hd/LRBrain.html>)
- [5] Right-Brain Hemisphere. (<http://psychology.jrank.org/pages/545/Right-Brain-Hemisphere.html>)
- [6] Gerald Holton, Yehuda Elkana. *Albert Einstein: Historical and Cultural Perspectives*, Dover Publications, July 1997, p. 97. ISBN 0486298795 "The workings of intuition transcend those of the intellect, and as is well known, innovation is often a triumph of intuition over logic."
- [7] Peter Steinfels Beliefs (<http://www.nytimes.com/1996/07/13/us/beliefs-080624.html>) *The New York Times*, July 13, 1996.
- [8] C.G. Jung. *Psychological Types*. Bollingen Series XX, Volume 6, Princeton University Press, 1971.
- [9] Mary H. McCaulley and Charles R. Martin. "Career Assessment and the MBTI (<http://jca.sagepub.com/content/3/2/219>)", *Journal of Career Assessment* 1995 3:219 DOI: 10.1177/106907279500300208.
- [10] Klein, Gary. *Intuition At Work*. Random House, NY, NY. January, 2003.
- [11] Allen Chuck Ross, "Brain Hemispheric Functions and the Native American," *Journal of American Indian Education*, August 1989. (<http://jaie.asu.edu/sp/V21S3bra.htm>)
- [12] Eugene Sadler-Smith. *Inside Intuition*. 2008.
- [13] Bishop, Paul (2000). *Synchronicity and Intellectual Intuition in Kant, Swedenborg, and Jung*. The Edwin Mellen Press. pp. 17–20. ISBN 0773475931.
- [14] Sri Aurobindo, *The Life Divine*, Sri Aurobindo Publication Department, 1970, p.65. ISBN 81-7058-187-7.
- [15] Alice A. Bailey, *The Light of the Soul*, Lucis Publishing Company, 1927, p. 317. ISBN B000XPMTB0.
- [16] Sri Aurobindo, *The Life Divine*, Sri Aurobindo Publication Department, 1970, p. 69. ISBN 81-7058-187-7.
- [17] Thomas Merton *The Literary Essays of Thomas Merton*, New Directions Publishing, March 1985, pp. 341, 348. ISBN 0811209318.
- [18] Thomas Merton, *The Literary Essays of Thomas Merton*, New Directions Publishing, March 1985, p. 364. ISBN 0811209318.
- [19] Lorenzo Ravagli, *Zanders Erzählungen*, Berliner Wissenschafts-Verlag, ISBN 978-3-8305-1613, pp. 680ff.
- [20] Idries Shah, *Thinkers of the East*, pp. 191 et seq, ISBN 0 224 61912 8 c/r 1971.
- [21] AJ Giannini, J Daood, MC Giannini, R Boniface, PG Rhodes. Intellect versus intuition--dichotomy in the reception of nonverbal communication. *Journal of General Psychology*. 99:19-24, 1978.
- [22] AJ Giannini, ME Barringer, MC Giannini, RH Loiselle. Lack of relationship between handedness and intuitive and intellectual (rationalistic) modes of information processing. *Journal of General Psychology*. 111:31-37 1984.
- [23] Anthony J. Pinizzotto, PhD, Edward F. Davis, MA, and Charles E. Miller III Emotional/rational decision making in law enforcement (<http://www.thefreelibrary.com/Emotional/rational+decision+making+in+law+enforcement-a0114370262>) (Federal Bureau of Investigation), *Free Online Library*, 2004.
- [24] *Encyclopedia of Creativity*, 2nd Edition.

[25] Intuition Peak. ([http://data.aad.gov.au/aadc/gaz/scar/display\\_name.cfm?gaz\\_id=134566](http://data.aad.gov.au/aadc/gaz/scar/display_name.cfm?gaz_id=134566)) SCAR Composite Gazetteer of Antarctica.

## Further reading

- Chopra, Deepak, and Judith Orloff. *The Power of Intuition*. Hay House, 2005. (Audio) ISBN 978-1401906221
- Davis, Elizabeth. *Women's Intuition*. Celestial Arts, 1989. ISBN 978-0890875728
- Mayer, Elizabeth Lloyd. *Extraordinary Knowing: Science, Skepticism, and the Inexplicable Powers of the Human Mind*. Bantam, 2008. ISBN 978-0553382235
- McTaggart, Lynn. *The Intention Experiment*. Free Press, 2008. ISBN 978-0743276962
- Schulz, Mona Lisa, and Christiane Northrup. *Awakening Intuition*. Three Rivers Press, 1999. ISBN 978-0-609-80424-7
- Sheldrake, Rupert. *Dogs That Know When Their Owners Are Coming Home: And Other Unexplained Powers of Animals*. Three Rivers Press, 2000. ISBN 978-0609805336
- Sheldrake, Rupert. *The Sense of Being Stared At: And Other Aspects of the Extended Mind*. Crown, 2003. ISBN 978-0609608074
- Sheldrake, Rupert. *Seven Experiments That Could Change the World: A Do-It-Yourself Guide to Revolutionary Science*. Park Street Press, 2002. ISBN 978-0892819898
- Wilde, Stuart. *Intuition*. Hay House, 1996. (Audio) ISBN 978-1401906740
- Wilde, Stuart. *The Sixth Sense: Including the Secrets of the Etheric Subtle Body*. Hay House, 2000. ISBN 978-1561705016
- Levin, Michal. *Spiritual Intelligence: Awakening the Power of Your Spirituality and Intuition*. Hodder & Stoughton, 2000. ISBN 978-0340733943
- Doc Childre and Howard Martin. *The HEARTMATH Solution*. HarperSanFrancisco, 1999. ISBN 978-0062516060
- Hoeflich, Christine. *What Everyone Believed: A Memoir of Intuition and Awakening*. Between Worlds Publishing, 2008. ISBN 978-0979658907

## External links

- A scientific research group on intuition (<http://www.intuition-sciences.com/>)
- Ask Philosophers: Question on Intuition and Rationality (<http://www.amherst.edu/askphilosophers/question/1533>)

# Metaphor

**Metaphor** is the concept of understanding one thing in terms of another. A **metaphor** is a figure of speech that constructs an analogy between two things or ideas; the analogy is conveyed by the use of a metaphorical word in place of some other word. For example: "Her eyes were glistening jewels".

*Metaphor* is or was also occasionally used to denote rhetorical figures of speech that achieve their effects via association, comparison or resemblance (e.g., antithesis, hyperbole, metonymy and simile, which are then all considered types of metaphor). Aristotle used both this sense and the regular, current sense above.<sup>[3]</sup>

The word *metaphor* derives from the 16th century Old French *métaphore*, in turn from the Latin *metaphora*, "carrying over", which is the latinisation of the Greek μεταφορά (*metaphorá*), "transfer",<sup>[4]</sup> from μεταφέρω (*metaphero*), "to carry over", "to transfer",<sup>[5]</sup> itself a compound of μετά (*meta*), "between"<sup>[6]</sup> + φέρω (*pherō*), "to bear", "to carry".<sup>[7]</sup>

## Types, terms and categories

Metaphors are comparisons that show how two things that are not alike in most ways are similar in one important way. A metaphor is more forceful (active) than an analogy, because metaphor asserts two things are the same, whereas analogy implies a difference; other rhetorical comparative figures of speech, such as metonymy, parable, simile and synecdoche, are species of metaphor distinguished by how the comparison is communicated.<sup>[3]</sup> The metaphor category also contains these specialised types:

- **allegory**: An extended metaphor wherein a story illustrates an important attribute of the subject.
- **catachresis**: A mixed metaphor used by design and accident (a rhetorical fault).
- **parable**: An extended metaphor narrated as an anecdote illustrating and teaching a moral lesson.

## Common types

- A **dead metaphor** is one in which the sense of a transferred image is absent. Examples: "to grasp a concept" and "to gather what you've understood" use physical action as a metaphor for understanding. Most people do not visualize the action — dead metaphors normally go unnoticed. Some people distinguish between a dead metaphor and a cliché. Others use "dead metaphor" to denote both.
- An **extended metaphor (conceit)**, establishes a principal subject (comparison) and subsidiary subjects (comparisons). The *As You Like It* quotation is a good example, the world is described as a stage, and then men and women are subsidiary subjects further described in the same context.
- A **mixed metaphor** is one that leaps from one identification to a second identification inconsistent with the first. Example: "If we can hit that bullseye then the rest of the dominoes will fall like a house of cards... Checkmate." Quote from Futurama TV show character Zapp Brannigan.<sup>[8]</sup>
- Per Hans Blumenberg's metaphorology, **absolute metaphor** denotes a figure or a concept that cannot be reduced to, or replaced with solely conceptual thought and language. Absolute metaphors, e.g. "light" (for "truth") and "seafaring" (for "human existence") – have distinctive meanings (unlike the literal meanings), and, thereby,



A **visual metaphor**: the front cover of the book *101 Billionaires* (published 2008, with photography by Rob Hornstra and text by Hans Loos and Arnold van Bruggen). While its title derives from the assertion in the Russian magazine *Finans*<sup>[1]</sup> that Russia then had 101 (US dollar) billionaires, the book portrays Russians who were pummeled by this huge transfer of wealth.<sup>[2]</sup>

function as orientations in the world, and as theoretic questions, such as presenting the world as a whole. Because they exist at the pre-predicative level, express and structure pragmatic and theoretical views of Man and the World.

### Use outside of rhetoric

The term metaphor is also used for the following terms that are not a part of rhetoric:

- A **cognitive metaphor** is the association of an object to an experience outside the object's environment.
- A **conceptual metaphor** is an underlying association that is systematic in both language and thought.
- A **root metaphor** is the underlying worldview that shapes an individual's understanding of a situation.
- A **therapeutic metaphor** is an experience that allows one to learn about more than just that experience.
- A visual metaphor provides a frame or window on experience. Metaphors can also be implied and extended throughout pieces of literature.

### History in literature and language

Metaphor is present in the oldest written Sumerian language narrative, the Epic of Gilgamesh:

Beloved friend, swift stallion, wild deer, / leopard ranging in the wilderness — / Enkidu, my friend, swift stallion, wild deer, / leopard ranging in the wilderness — / together we crossed the mountains, together / we slaughtered the Bull of Heaven, we killed / Humbaba, who guarded the Cedar Forest — / O Enkidu, what is this sleep that has seized you, / that has darkened your face and stopped your breath?— (Trans. Mitchell, 2004)

In this example, the friend is compared to a stallion, a wild deer, and a leopard to indicate that the speaker sees traits from these animals in his friend (A comparison between two or more unlike objects).

The idea of metaphor can be traced back to Aristotle who, in his “Poetics” (around 335 BC), defines “metaphor” as follows: “Metaphor is the application of a strange term either transferred from the genus and applied to the species or from the species and applied to the genus, or from one species to another or else by analogy.”<sup>[9]</sup> For the sake of clarity and comprehension it might additionally be useful to quote the following two alternative translations: “Metaphor is the application of an alien name by transference either from genus to species, or from species to genus, or from species to species, or by analogy, that is, proportion.”<sup>[10]</sup> Or, as Halliwell puts it in his translation: “Metaphor is the application of a word that belongs to another thing: either from genus to species, species to genus, species to species, or by analogy.”<sup>[11]</sup>

Therefore, the key aspect of a metaphor is a specific transference of a word from one context into another. With regard to the four kinds of metaphors which Aristotle distincts against each other the last one (transference by analogy) is the most eminent one so that all important theories on metaphor have a reference to this characterization.

The Greek plays of Sophocles, Aeschylus, and Euripides, among others, were almost invariably allegorical, showing the tragedy of the protagonists, either to caution the audience metaphorically about temptation, or to lambast famous individuals of the day by inferring similarities with the caricatures in the play.

Even when they are not intentional, they can be drawn between most writing or language and other topics. In this way it can be seen that any theme in literature is a metaphor, using the story to convey information about human perception of the theme in question.

## In historical linguistics

In historical onomasiology or, more generally, in historical linguistics, metaphor is defined as semantic change based on similarity, i.e. a similarity in form or function between the original concept named by a word and the target concept named by this word.<sup>[12]</sup>

ex. **mouse**: *small, gray rodent* → *small, gray, mouse-shaped computer device*.

Some recent linguistic theories view language as by its nature all metaphorical; or that language in essence is metaphorical.<sup>[13]</sup>

## Historical theories of metaphor

### Metaphor as style in speech and writing

Viewed as an aspect of speech and writing, metaphor qualifies as style, in particular, style characterized by a type of analogy. An expression (word, phrase) that by implication suggests the likeness of one entity to another entity gives style to an item of speech or writing, whether the entities consist of objects, events, ideas, activities, attributes, or almost anything expressible in language. For example, in the first sentence of this paragraph, the word "viewed" serves as a metaphor for "thought of", implying analogy of the process of seeing and the thought process. The phrase, "viewed as an aspect of", projects the properties of seeing (vision) something from a particular perspective onto thinking about something from a particular perspective, that "something" in this case referring to "metaphor" and that "perspective" in this case referring to the characteristics of speech and writing.

As a characteristic of speech and writing, metaphors can serve the poetic imagination, enabling William Shakespeare, in his play "As You Like It", to compare the world to a stage and its human inhabitants players entering and exiting upon that stage;<sup>[14]</sup> enabling Sylvia Plath, in her poem "Cut", to compare the blood issuing from her cut thumb to the running of a million soldiers, "redcoats, every one";<sup>[15]</sup> and, enabling Robert Frost, in "The Road Not Taken", to compare one's life to a journey.<sup>[16]</sup>

Viewed also as an aspect of speech, metaphor can serve as a device for persuading the listener or reader of the speaker-writer's argument or thesis, the so-called rhetorical metaphor...

### Metaphor as foundational to our conceptual system

Cognitive linguists emphasize that metaphors serve to facilitate the understanding of one conceptual domain, typically an abstract one like 'life' or 'theories' or 'ideas', through expressions that relate to another, more familiar conceptual domain, typically a more concrete one like 'journey' or 'buildings' or 'food'.<sup>[17] [18]</sup> *Food for thought*: we devour a book of raw facts, try to digest them, stew over them, let them simmer on the back-burner, regurgitate them in discussions, cook up explanations, hoping they do not seem half-baked. Theories as buildings: we establish a foundation for them, a framework, support them with strong arguments, buttressing them with facts, hoping they will stand. Life as journey: some of us travel hopefully, others seem to have no direction, many lose their way.

A convenient short-hand way of capturing this view of metaphor is the following: CONCEPTUAL DOMAIN (A) IS CONCEPTUAL DOMAIN (B), which is what is called a conceptual metaphor. A conceptual metaphor consists of two conceptual domains, in which one domain is understood in terms of another. A conceptual domain is any coherent organization of experience. Thus, for example, we have coherently organized knowledge about journeys that we rely on in understanding life.<sup>[18]</sup>

How does this relate to the nature and importance of our conceptual system, and to metaphor as foundational to our conceptual system?

## More than just a figure of speech

Some theorists have suggested that metaphors are not merely stylistic, but that they are cognitively important as well. In *Metaphors We Live By* George Lakoff and Mark Johnson argue that metaphors are pervasive in everyday life, not just in language, but also in thought and action. A common definition of a metaphor can be described as a comparison that shows how two things that are not alike in most ways are similar in another important way. They explain how a metaphor is simply understanding and experiencing one kind of thing in terms of another. The authors call this concept a 'conduit metaphor.' By this they meant that a speaker can put ideas or objects into words or containers, and then send them along a channel, or conduit, to a listener who takes that idea or object out of the container and makes meaning of it. In other words, communication is something that ideas go into. The container is separate from the ideas themselves. Lakoff and Johnson give several examples of daily metaphors we use, such as "argument is war" and "time is money." Metaphors are widely used in context to describe personal meaning. The authors also suggest that communication can be viewed as a machine: "Communication is not what one does with the machine, but is the machine itself." (Johnson, Lakoff, 1980).<sup>[19]</sup>

## Notes

- [1] As reported in Felix Lowe, "Deripaska eclipses Abramovich in rich list (<http://www.telegraph.co.uk/finance/newsbysector/energy/2784571/Deripaska-eclipses-Abramovich-in-rich-list.html>)", *The Telegraph* (London), 18 February 2008. Accessed 10 March 2011.
- [2] "Forgotten by capitalism ([http://designmind.frogdesign.com/articles/power/forgotten-by-capitalism.html?#/images/dm/dm10\\_forgotten\\_by\\_capitalism\\_slide\\_1.jpg](http://designmind.frogdesign.com/articles/power/forgotten-by-capitalism.html?#/images/dm/dm10_forgotten_by_capitalism_slide_1.jpg))", *Design Mind*, n.d. Accessed 10 March 2011.
- [3] *The Oxford Companion to the English Language* (1992) pp.653–55: "A rhetorical figure with two senses, both originating with Aristotle in the 4c BC: (I) All figures of speech that achieve their effects through association, comparison and resemblance. Figures like antithesis, hyperbole, metonymy and simile are [in that sense] all species of metaphor. [But] this sense is not current, ..."
- [4] Metaphora (<http://www.perseus.tufts.edu/cgi-bin/ptext?doc=Perseus:text:1999.04.0057:entry=#67015>), Henry George Liddell, Robert Scott, *A Greek-English Lexicon*, at Perseus
- [5] Metaphero (<http://www.perseus.tufts.edu/cgi-bin/ptext?doc=Perseus:text:1999.04.0057:entry=#67010>), Henry George Liddell, Robert Scott, *A Greek-English Lexicon*, at Perseus
- [6] Meta (<http://www.perseus.tufts.edu/cgi-bin/ptext?doc=Perseus:text:1999.04.0057:entry=#66573>), Henry George Liddell, Robert Scott, *A Greek-English Lexicon*, at Perseus
- [7] Phero (<http://www.perseus.tufts.edu/cgi-bin/ptext?doc=Perseus:text:1999.04.0057:entry=#110599>), Henry George Liddell, Robert Scott, *A Greek-English Lexicon*, at Perseus
- [8] Zapp Brannigan (Character) – Quotes (<http://www.imdb.com/character/ch0013045/quotes>)
- [9] Aristotle in 23 Volumes, Vol. 23, translated by W.H. Fyfe. Cambridge, MA, Harvard University Press; London, William Heinemann Ltd. 1932, 1457b.
- [10] Aristotle, Poetics, trans. I. Bywater, in *The Complete Works of Aristotle*, ed. Jonathan Barnes (Princeton: Princeton University Press, 1984), vol 2, 1457b.
- [11] Aristotle: Poetics. Translated by Stephen Halliwell; Longinus: On the Sublime; Demetrius: On Style (Loeb Classical Library No. 199), 1996, 1457b.
- [12] Cf. Joachim Grzega (2004), *Bezeichnungswandel: Wie, Warum, Wozu? Ein Beitrag zur englischen und allgemeinen Onomasiologie*, Heidelberg: Winter, and Blank, Andreas (1997), *Prinzipien des lexikalischen Bedeutungswandels am Beispiel der romanischen Sprachen*, Tübingen: Niemeyer.
- [13] See, for example, Vilayanur S Ramachandran, Reith Lectures 2003 The Emerging Mind, lecture 4 "Purple Numbers and Sharp Cheese", BBC (<http://www.bbc.co.uk/radio4/reith2003/lecture4.shtml>)
- [14] "As You Like It": Entire play (<http://shakespeare.mit.edu/asyoulikeit/full.html>) From: The Complete Works of William Shakespeare (<http://shakespeare.mit.edu/>)
- [15] "Cut" by Sylvia Plath (<http://www.sylviaiplathforum.com/thread2.html>) From: The Sylvia Plath Forum (<http://www.sylviaiplathforum.com/index.shtml>)
- [16] "The Road Not Taken" by Robert Frost (<http://www.bartleby.com/119/1.html>) From: Bartleby.com: Great Books Online (<http://www.bartleby.com/>)
- [17] Lakoff G., Johnson M. (1980, 2003). *Metaphors We Live By*. Chicago: University of Chicago Press. ISBN 0226468011.
- [18] Zoltán Kövecses. (2002) *Metaphor: a practical introduction*. Oxford University Press US. ISBN 9780195145113.
- [19] Lakoff, G. & Johnson, M. *Metaphors We Live By* (IL: University of Chicago Press, 1980), Chapters 1–3. (pp. 3–13).

## References

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- Stefano Arduini (2007). (ed.) *Metaphors*, Roma, Edizioni di Storia e Letteratura.
- Aristotle. *Poetics*. Trans. I. Bywater. In *The Complete Works of Aristotle: The Revised Oxford Translation*. (1984). 2 Vols. Ed. Jonathan Barnes. Princeton, Princeton University Press.
- I. A. Richards. (1936). *The Philosophy of Rhetoric*. Oxford, Oxford University Press.
- Max Black (1954). *Metaphor*, *Proceedings of the Aristotelian Society*, 55, pp. 273–294.
- Max Black (1962). *Models and metaphors: Studies in language and philosophy*, Ithaca: Cornell University Press.
- Max Black (1979). *More about Metaphor*, in A. Ortony (ed) *Metaphor & Thought*.
- Clive Cazeaux (2007). *Metaphor and Continental Philosophy: From Kant to Derrida*. New York: Routledge.
- L. J. Cohen (1979). *The Semantics of Metaphor*, in A. Ortony (ed) *Metaphor & Thought*
- Donald Davidson. (1978). "What Metaphors Mean." Reprinted in *Inquiries Into Truth and Interpretation*. (1984), Oxford, Oxford University Press.
- Jacques Derrida (1982). "White Mythology: Metaphor in the Text of Philosophy." In *Margins of Philosophy*. Trans. Alan Bass. Chicago, University of Chicago Press.
- Paul Ricoeur (1975). *The Rule of Metaphor: Multi-Disciplinary Studies in the Creation of Meaning in Language*, trans. Robert Czerny with Kathleen McLaughlin and John Costello, S. J., London: Routledge and Kegan Paul 1978. (Toronto: University of Toronto Press 1977)
- John Searle (1979). "Metaphor," in A. Ortony (ed) *Metaphor & Thought*
- Lakoff, G. & Johnson, M. *Metaphors We Live By* (IL: University of Chicago Press, 1980), Chapters 1–3. (pp. 3–13).

## External links

- History of metaphor (<http://www.bbc.co.uk/programmes/b00w227c>) on In Our Time at the BBC. ( listen now ([http://www.bbc.co.uk/iplayer/console/b00w227c/In\\_Our\\_Time\\_History\\_of\\_metaphor](http://www.bbc.co.uk/iplayer/console/b00w227c/In_Our_Time_History_of_metaphor)))
- *A short history of metaphor* (<http://web.archive.org/web/20070101145805/http://tscp.open.ac.uk/t185/html/resources/r2history.htm>)
- Audio illustrations of metaphor as figure of speech (<http://www.americanrhetoric.com/figures/metaphor.htm>)
- Center for the Cognitive Science of Metaphor Online (<http://zakros.ucsd.edu/~trohrer/metaphor/metaphor.htm>)
- *Critical Inquiry* (Autumn 1978) Special Issue: On Metaphors (<http://criticalinquiry.uchicago.edu/issues/v5/v5n1.html>)
- Top Ten Metaphors of 2008 (<http://www.metaphorobservatory.com/2009/07/top-ten-metaphors-of-2008/>)
- Shakespeare's Metaphors (<http://shakespeare-online.com/biography/metaphorlist.html>)
- Metaphor Examples (categorized) ([http://knowgramming.com/metaphors/metaphor\\_chapters/examples.htm](http://knowgramming.com/metaphors/metaphor_chapters/examples.htm))
- Metaphor's Algebra (<http://www.bentamari.com/metaphors.html>)
- List of ancient Greek words starting with *μετα-* (<http://www.perseus.tufts.edu/hopper/resolveform?type=start&lookup=meta&lang=greek>), on Perseus

# Ideas bank

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An **ideas bank** is a website where people post, exchange, discuss, and polish new ideas. Some ideas banks are used for the purpose of developing new inventions or technologies. Many corporations have installed internal ideas banks to gather the input from their employees and improve their ideation process. Some ideas banks employ a voting system to estimate an idea's value. In some cases, ideas banks can be more humor-oriented than their serious counterparts. The underlying theory of an ideas bank is that if a large group of people collaborate on a project or the development of an idea that eventually said project or idea will reach perfection in the eyes of those who worked on it.

Many ideas banks are provided as free of charge, or set around certain companies in general to work out new inventions. Although ideas are provided by a community of people, problems can arise when people take the ideas of the site and begin developing them. There is no possible way to prove that the idea on the ideas bank was original and not taken from something else.

## Examples

As part of the adoption of enterprise social software, many companies have decided to use such a portal to allow their employees (on the intra-net) or their customers (on the internet) to collaborate in the process of raising new ideas.

Idea management software has the sole purpose of raising new ideas — for new products, process improvements, employee welfare or any other corporate use.

Although not necessarily ideas banks *per se*, by allowing anyone to edit, wikis allow a group of people to work on information collaboratively. This collaborative writing can continue until all are satisfied with the article or piece of writing, but more often than not contributions continue as visitors add information, improve what is already there, and remove irrelevant or incorrect information.

Halfbakery is an example of a slightly less serious ideas bank. Users submit ideas, often jokingly, which are then commented on, often jokingly, by other users.

The Global Ideas Bank is the opposite of Halfbakery in that ideas are proposed seriously, and in some cases actually implemented. It started as a group of inventors in 1985 and became a large organization over several years until it was put online with its current name in 1995.

Founded in London in 2000, Idea A Day solicits submissions of original ideas from around the world, edits and publishes one considered example every day. A book, *The Big Idea Book*, comprising 500 of the best ideas was published by Wiley in 2003.

## External links

- Taylor, William C. (2006-03-26). "Here's an Idea: Let Everyone Have Ideas"<sup>[1]</sup>. The New York Times. Retrieved 2007-12-27.
- Ideas Banks<sup>[2]</sup> at the Open Directory Project

## References

- [1] <http://www.nytimes.com/2006/03/26/business/yourmoney/26mgmt.html?ex=1301029200&en=0d90ed5116e769d0&ei=5090>
- [2] [http://www.dmoz.org/Computers/Open\\_Source/Open\\_Content/Idea\\_Banks/](http://www.dmoz.org/Computers/Open_Source/Open_Content/Idea_Banks/)



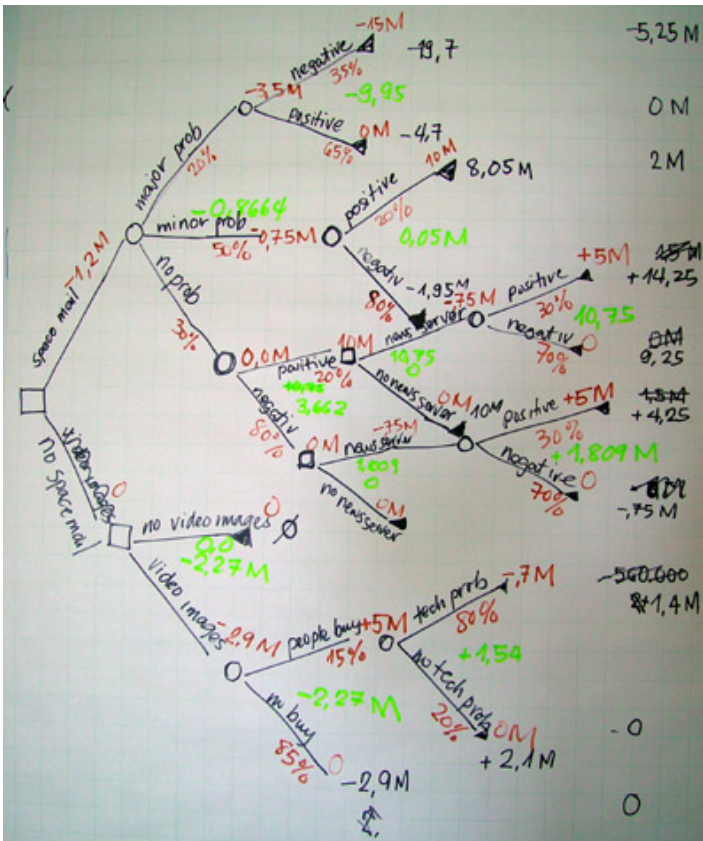
# Decision tree

A **decision tree** is a decision support tool that uses a tree-like graph or model of decisions and their possible consequences, including chance event outcomes, resource costs, and utility. It is one way to display an algorithm. Decision trees are commonly used in operations research, specifically in decision analysis, to help identify a strategy most likely to reach a goal. Another use of decision trees is as a descriptive means for calculating conditional probabilities. When the decisions or consequences are modelled by computational verb, then we call the decision tree a computational verb decision tree.<sup>[1]</sup>

## General

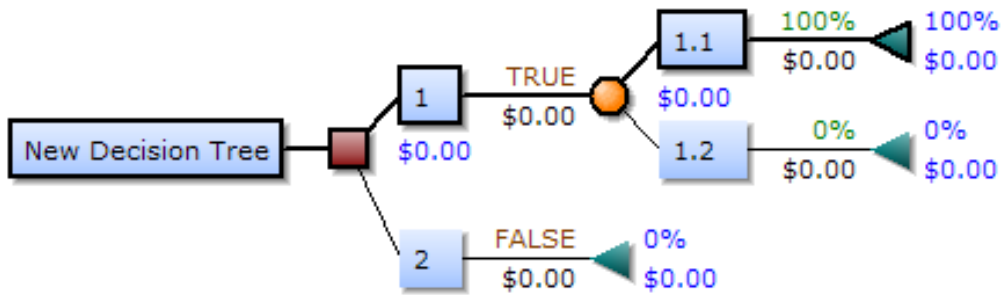
In decision analysis, a "decision tree" — and the closely-related influence diagram — is used as a visual and analytical decision support tool, where the expected values (or expected utility) of competing alternatives are calculated.

Decision trees have traditionally been created manually, as the following example shows:



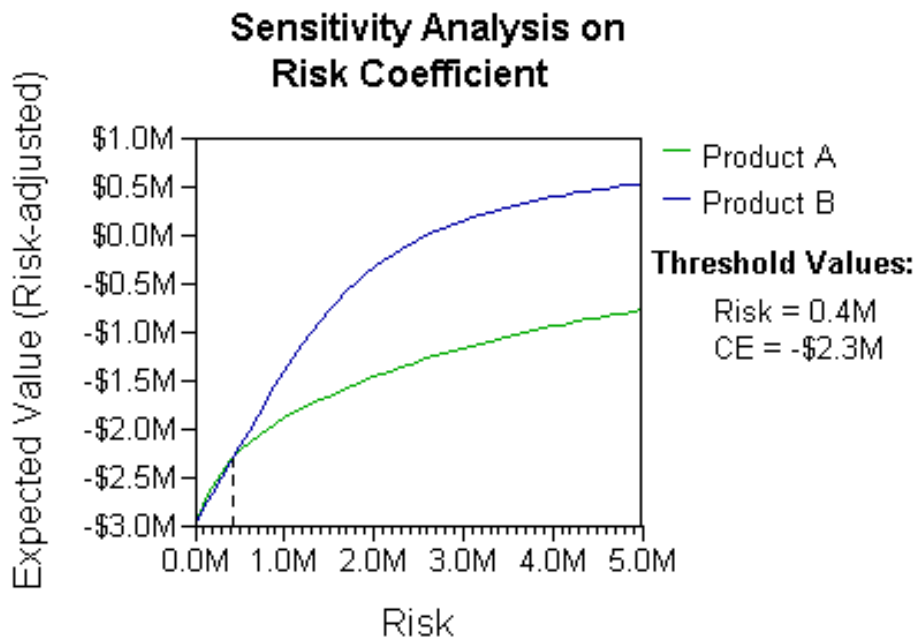
A decision Tree consists of 3 types of nodes:-

1. Decision nodes - commonly represented by squares
2. Chance nodes - represented by circles
3. End nodes - represented by triangles



Drawn from left to right, a decision tree has only burst nodes (splitting paths) but no sink nodes (converging paths). Therefore, used manually, they can grow very big and are then often hard to draw fully by hand.

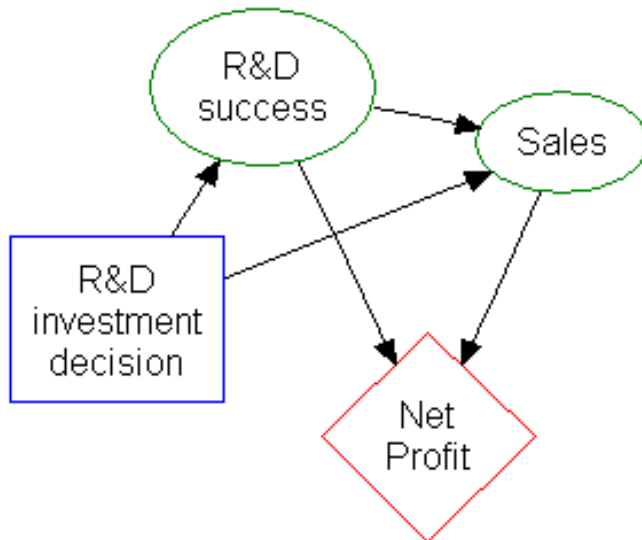
Analysis can take into account the decision maker's (e.g., the company's) preference or utility function, for example:



The basic interpretation in this situation is that the company prefers B's risk and payoffs under realistic risk preference coefficients (greater than \$400K—in that range of risk aversion, the company would need to model a third strategy, "Neither A nor B").

## Influence diagram

A decision tree can be represented more compactly as an influence diagram, focusing attention on the issues and relationships between events.



## Uses in teaching

Decision trees, influence diagrams, utility functions, and other decision analysis tools and methods are taught to undergraduate students in schools of business, health economics, and public health, and are examples of operations research or management science methods.

## Advantages

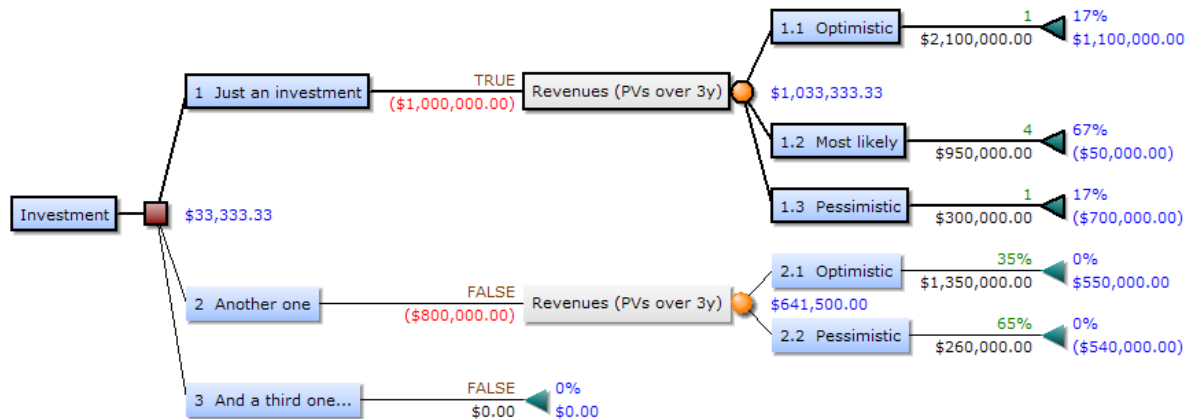
Amongst decision support tools, decision trees (and influence diagrams) have several advantages:

Decision trees:

- **Are simple to understand and interpret.** People are able to understand decision tree models after a brief explanation.
- **Have value even with little hard data.** Important insights can be generated based on experts describing a situation (its alternatives, probabilities, and costs) and their preferences for outcomes.
- **Use a white box model.** If a given result is provided by a model, the explanation for the result is easily replicated by simple math.
- **Can be combined with other decision techniques.** The following example uses Net Present Value calculations, PERT 3-point estimations (decision #1) and a linear distribution of expected outcomes (decision #2):

## Example

Decision trees can be used to optimize an investment portfolio. The following example shows a portfolio of 7 investment options (projects). The organization has \$10,000,000 available for the total investment. Bold lines mark the best selection 1, 3, 5, 6, and 7, which will cost \$9,750,000 and create a payoff of 16,175,000. All other combinations would either exceed the budget or yield a lower payoff.<sup>[2]</sup>



## Example

In the game of "20 Questions", the querent tries to construct a short binary decision tree that isolates a specific item. The item's identity question is asked when the current decision tree node is considered reliable by the querent.

## References

- [1] Yang, T. (Dec. 2006). "Computational Verb Decision Trees". *International Journal of Computational Cognition* (Yang's Scientific Press) 4 (4): 34–46.
- [2] Y. Yuan and M.J. Shaw, Induction of fuzzy decision trees ([http://www.sciencedirect.com/science?\\_ob=ArticleURL&\\_udi=B6V05-4007D5X-C&\\_user=793840&\\_coverDate=01/27/1995&\\_fmt=summary&\\_orig=search&\\_cdi=5637&view=c&\\_acct=C000043460&\\_version=1&\\_urlVersion=0&\\_userid=793840&md5=b66b56153f6780c30e07201eadd454cf&ref=full](http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6V05-4007D5X-C&_user=793840&_coverDate=01/27/1995&_fmt=summary&_orig=search&_cdi=5637&view=c&_acct=C000043460&_version=1&_urlVersion=0&_userid=793840&md5=b66b56153f6780c30e07201eadd454cf&ref=full)). *Fuzzy Sets and Systems* 69 (1995), pp. 125–139

## External links

- 5 Myths About Decision Tree Analysis in Litigation (<https://paperchace.com/decision-trees/?p=6>)
- Decision Tree Analysis ([http://www.mindtools.com/pages/article/newTED\\_04.htm](http://www.mindtools.com/pages/article/newTED_04.htm)) mindtools.com
- Decision Analysis open course at George Mason University (<http://gunston.gmu.edu/healthscience/730/default.asp>)
- Extensive Decision Tree tutorials and examples (<http://www.public.asu.edu/~kirkwood/DAStuff/decisontrees/index.html>)
- Cha, Sung-Hyuk; Tappert, Charles C (2009). "A Genetic Algorithm for Constructing Compact Binary Decision Trees" (<http://www.jprr.org/index.php/jprr/article/view/44/25>). *Journal of Pattern Recognition Research* (<http://www.jprr.org/index.php/jprr>) 4 (1): 1–13.
- Decision Trees in PMML (<http://www.dmg.org/v4-0/TreeModel.html>)

# Association (psychology)

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In psychology and marketing, two concepts or stimuli are **associated** when the experience of one leads to the effects of another, due to repeated pairing. This is sometimes called **Pavlovian association** for Ivan Pavlov's pioneering of classical conditioning.

Association is a widely used memory tool. Associating a new item (an object, a picture, a smell or anything else a person may wish to recall) to another, more easily-remembered item can allow you to think of them both.

## External links

- *Dictionary of the History of Ideas*: <sup>[1]</sup> Association of Ideas
- Time Associations: <sup>[2]</sup> Associations we have with numbers on a digital clock
- Word Associations Network: <sup>[3]</sup> The Word Association Dictionary

## References

[1] [http://virgobeta.lib.virginia.edu/catalog?id=digital\\_collection\\_facet&q=Dictionary+of+the+History+of+Ideas](http://virgobeta.lib.virginia.edu/catalog?id=digital_collection_facet&q=Dictionary+of+the+History+of+Ideas)

[2] <http://www.timeassociation.net/>

[3] <http://wordassociations.net/search?hl=en&q=sky>

# Random juxtaposition

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**Random juxtaposition** refers to the stimulation of creativity in problem solving, design or other creative pursuit by confronting two unrelated concepts or objects, usually the goal or problem to be solved on the one hand and a randomly selected object or concept on the other. Similar to an oxymoron.

# Creative destruction

**Creative destruction** is a term originally derived from Marxist economic theory which refers to the linked processes of the accumulation and annihilation of wealth under capitalism. These processes were first described in *The Communist Manifesto* (Marx and Engels, 1848)<sup>[1]</sup> and were expanded in Marx's *Grundrisse* (1857)<sup>[2]</sup> and "Volume IV" (1863) of *Das Kapital*.<sup>[3]</sup> At its most basic, "creative destruction" (German: *schöpferische Zerstörung*) describes the way in which capitalist economic development arises out of the destruction of some prior economic order, and this is largely the sense implied by the German Marxist sociologist Werner Sombart who has been credited<sup>[4]</sup> with the first use of these terms in his work *Krieg und Kapitalismus* ("War and Capitalism", 1913).<sup>[5]</sup> In the earlier work of Marx, however, the idea of creative destruction or annihilation (German: *Vernichtung*) implies not only that capitalism destroys and reconfigures previous economic orders, but that it must ceaselessly devalue existing wealth (whether through war, dereliction, or regular and periodic economic crises) in order to clear the ground for the creation of new wealth.<sup>[1] [2] [3]</sup>



Crowd at New York's American Union Bank during a bank run early in the Great Depression.

Marx argued that the devaluation of wealth during capitalism's periodic economic crises was an inevitable outcome of the processes of wealth creation.

From the 1950s onwards, the term "creative destruction" has become more readily identified with the Austrian-American economist Joseph Schumpeter,<sup>[4]</sup> who adapted and popularized it as a theory of economic innovation and progress. The term, as used by Schumpeter, bears little resemblance with how it was used by Marx. As such, the term gained popularity within neoliberal or free-market economics as a description of processes such as downsizing in order to increase the efficiency and dynamism of a company. The original Marxist usage has, however, been maintained in the work of influential social scientists such as David Harvey,<sup>[6]</sup> Marshall Berman,<sup>[7]</sup> and Manuel Castells.<sup>[8]</sup>

## History

### In Marx's thought

In *The Communist Manifesto* of 1848, Karl Marx and Friedrich Engels described the crisis tendencies of capitalism in terms of "the enforced destruction of a mass of productive forces":

Modern bourgeois society, with its relations of production, of exchange and of property, a society that has conjured up such gigantic means of production and of exchange, is like the sorcerer who is no longer able to control the powers of the nether world whom he has called up by his spells. [...] It is enough to mention the commercial crises that by their periodical return put the existence of the whole of bourgeois society on trial, each time more threateningly. In these crises, *a great part not only of existing production, but also of previously created productive forces, are periodically destroyed*. In these crises, there breaks out an epidemic that, in all earlier epochs, would have seemed an absurdity — the epidemic of over-production. Society suddenly finds itself put back into a state of momentary barbarism; it appears as if a famine, a universal war of devastation, had cut off the supply of every means of subsistence; industry and commerce seem to be destroyed; and why? Because there is too much civilisation, too much means of subsistence, too much industry, too much commerce. The productive forces at the disposal of society no longer tend to further the development of the conditions of bourgeois property; on the contrary, they have become too powerful for these conditions. [...] And how does the bourgeoisie get over these crises? On the one hand by *enforced destruction*

*of a mass of productive forces*; on the other, by the conquest of new markets, and by the more thorough exploitation of the old ones. That is to say, by paving the way for more extensive and more destructive crises, and by diminishing the means whereby crises are prevented.<sup>[1]</sup>

A few years later, in the *Grundrisse*, Marx was writing of "the violent destruction of capital not by relations external to it, but rather as a condition of its self-preservation".<sup>[2]</sup> In other words, he establishes a necessary link between the generative or creative forces of production in capitalism and the destruction of capital value as one of the key ways in which capitalism attempts to overcome its internal contradictions:

These contradictions lead to explosions, cataclysms, crises, in which [...] momentaneous suspension of labour and annihilation of a great portion of capital [...] violently lead it back to the point where it is enabled [to go on] fully employing its productive powers without committing suicide.<sup>[2] [9]</sup>

In the *Theories of Surplus Value* ("Volume IV" of *Das Kapital*, 1863), Marx refines this theory to distinguish between scenarios where the destruction of (commodity) values affects either use values or exchange values or both together.<sup>[6]</sup> The destruction of exchange value combined with the preservation of use value presents clear opportunities for new capital investment and hence for the repetition of the production-devaluation cycle:

the destruction of capital through crises means the depreciation of values which prevents them from later renewing their reproduction process as capital on the same scale. This is the ruinous effect of the fall in the prices of commodities. It does not cause the destruction of any use-values. What one loses, the other gains. Values used as capital are prevented from acting again as capital in the hands of the same person. The old capitalists go bankrupt. [...] A large part of the nominal capital of the society, i.e., of the exchange-value of the existing capital, is once for all destroyed, although this very destruction, since it does not affect the use-value, may very much expedite the new reproduction. This is also the period during which moneyed interest enriches itself at the cost of industrial interest.<sup>[10]</sup>

Although the modern term "creative destruction" is not used explicitly by Marx, it is clear that subsequent usage of it derives from these analyses, particularly in the work of Werner Sombart (whom Engels described as the only German professor who understood Marx's *Capital*),<sup>[11]</sup> and of Joseph Schumpeter (see below). Social geographer David Harvey sums up the differences between Marx's usage of these concepts and Schumpeter's: "Both Karl Marx and Joseph Schumpeter wrote at length on the 'creative-destructive' tendencies inherent in capitalism. While Marx clearly admired capitalism's creativity he [...] strongly emphasised its self-destructiveness. The Schumpeterians have all along gloried in capitalism's endless creativity while treating the destructiveness as mostly a matter of the normal costs of doing business".<sup>[12]</sup>

## Other early usage

In philosophical terms, the concept of "creative destruction" is close to Hegel's concept of sublation. In German economic discourse it was taken up from Marx's writings by Werner Sombart, particularly in his 1913 text *Krieg und Kapitalismus*.<sup>[13]</sup>

Again, however, *from destruction a new spirit of creation arises*; the scarcity of wood and the needs of everyday life... forced the discovery or invention of substitutes for wood, forced the use of coal for heating, forced the invention of coke for the production of iron.

It has been argued that Sombart's formulation of the concept was influenced by Eastern mysticism, specifically the image of the Hindu god Shiva, who is presented in the paradoxical aspect of simultaneous destroyer and creator.<sup>[4]</sup> Conceivably this influence passed from Johann Gottfried Herder, who brought Hindu thought to German philosophy in his *Philosophy of Human History* (*Ideen zur Philosophie der Geschichte der Menschheit*) (Herder 1790–92), specifically volume III, pp. 41–64.<sup>[4]</sup> via Arthur Schopenhauer and the Orientalist Friedrich Maier through Friedrich Nietzsche's writings. Nietzsche represented the creative destruction of modernity through the mythical figure of Dionysus, a figure whom he saw as at one and the same time "destructively creative" and "creatively destructive".<sup>[14]</sup>

Other 19th century formulations of this idea include Russian anarchist Mikhail Bakunin, who wrote in 1842, "The passion for destruction is a creative passion, too!"<sup>[15]</sup> Note, however, that this earlier formulation might more accurately be termed "destructive creation", and differs sharply from Schumpeter's formulation in the critical aspect of temporal precedence. For Schumpeter, the creation comes first; the destruction is an almost incidental effect of the creation.



In Hinduism, the god Shiva is simultaneously destroyer and creator, portrayed as *Shiva Nataraja* (Lord of the Dance), which is proposed as the source of the Western notion of "creative destruction".<sup>[4]</sup>

## Schumpeterian Creative Destruction

### Joseph Schumpeter

In the Anglo-Saxon world, the expression "creative destruction" was popularized by and is most associated with Joseph Schumpeter, particularly in his book *Capitalism, Socialism and Democracy*, first published in 1942. In *Capitalism, Socialism and Democracy*, Schumpeter popularized and used the term to describe the process of transformation that accompanies radical innovation.<sup>[16]</sup> In Schumpeter's vision of capitalism, innovative entry by entrepreneurs was the force that sustained long-term economic growth, even as it destroyed the value of established companies and laborers that enjoyed some degree of monopoly power derived from previous technological, organizational, regulatory, and economic paradigms. Schumpeter also elaborated the concept, making it central to his economic theory. The most likely source can be found in his 1939 book *Business Cycles*. Here the Western world first learned about Nikolai Kondratieff and his long-wave cycle. These cycles, Schumpeter believed, were caused by innovations.

Schumpeter (1949) in one of his examples used the 'the railroadization of the Middle West as it was initiated by the Illinois Central.' and how 'the Illinois Central not only meant very good business whilst it was built and whilst new cities were built around it and land was cultivated, but it spelled the death sentence for the [old] agriculture of the West.'<sup>[17]</sup>



## Examples

Companies that once revolutionized and dominated new industries – for example, Xerox in copiers<sup>[18]</sup> or Polaroid in instant photography have seen their profits fall and their dominance vanish as rivals launched improved designs or cut manufacturing costs. Wal-Mart is a recent example of a company that has achieved a strong position in many markets, through its use of new inventory-management, marketing, and personnel-management techniques, using its resulting lower prices to compete with older or smaller companies in the offering of retail consumer products. Just as older behemoths perceived to be juggernauts by their contemporaries (e.g., Montgomery Ward, FedMart, Woolworths) were eventually undone by nimbler and more innovative competitors, Wal-Mart faces the same threat. Just as the cassette tape replaced the 8-track, only to be replaced in turn by the compact disc, itself being undercut by MP3 players, the seemingly dominant Wal-Mart may well find itself an antiquated company of the past. This is the process of creative destruction in its technological manifestation.



Polaroid instant cameras have disappeared almost completely with the spread of digital photography.

Other examples are the way in which online free newspaper sites such as *The Huffington Post* and the *National Review Online* are leading to creative destruction of the traditional paper newspaper. The *Christian Science Monitor* announced in January 2009<sup>[19]</sup> that it would no longer continue to publish a daily paper edition, but would be available online daily and provide a weekly print edition. The *Seattle Post-Intelligencer* became online-only in March 2009.<sup>[20]</sup> Traditional French alumni networks, which typically charge their students to network online or through paper directories, are in danger of creative destruction from free social networking sites such as LinkedIn and Viadeo.<sup>[21]</sup>

In fact, successful innovation is normally a source of temporary market power, eroding the profits and position of old firms, yet ultimately succumbing to the pressure of new inventions commercialised by competing entrants. Creative destruction is a powerful economic concept because it can explain many of the dynamics or kinetics of industrial change: the transition from a competitive to a monopolistic market, and back again. It has been the inspiration of endogenous growth theory and also of evolutionary economics.<sup>[22]</sup>

David Ames Wells (1890), who was a leading authority on the effects of technology on the economy in the late 19th century, gave many examples of creative destruction (without using the term) brought about by improvements in steam engine efficiency, shipping, the international telegraph network and agricultural mechanization.<sup>[23]</sup>

## Downsides of Creative Destruction

Creative destruction can cause temporary economic distress. Layoffs of workers with obsolete working skills can be one price of new innovations valued by consumers. Though a continually innovating economy generates new opportunities for workers to participate in more creative and productive enterprises (provided they can acquire the necessary skills), creative destruction can cause severe hardship in the short term, and in the long term for those who cannot acquire the skills and work experience.

However, some believe that in the long-term society as a whole (including the descendants of those that experienced short-term hardship) enjoys a rise in overall quality of life due to the accumulation of innovation - for example, 90% of Americans were farmers in 1790, while 2.6% of Americans were farmers in 1990.<sup>[24]</sup> Over those 200 years farm jobs were destroyed by exponential productivity gains in agricultural technology and replaced by jobs in new industries. Present day farmers and non-farmers alike enjoy much more prosperous lifestyles than their counterparts in 1790.

In terms of individuals recovering from obsolescence caused by creative destruction, when a small entity lacks sufficient resources to retrain, this can lead to an absorbing state which may persist due to information asymmetries that restrict borrowing. Small entities or individuals may prefer in such cases to obtain insurance (particularly if they are risk averse), although again this may be a problem due to adverse selection. Large entities may wish to drive smaller entities to an absorbing state (as an anticompetitive practice. (See also Kreps et al's solution to Selten's chainstore paradox)(This can also be conceptualized as raising the stakes in no-limit poker). As a result, it may be more efficient for the overall economy to provide insurance - (perhaps even mandatory insurance in order to obtain a pooling equilibrium) - since insurance can give small entities and individuals sufficient resources to have the activation energy needed to retrain and escape the absorbing state.

## Later developments

### David Harvey

Radical geographer David Harvey in a series of works from the 1970s onwards (*Social Justice and the City*, 1973;<sup>[25]</sup> *The Limits to Capital*, 1982;<sup>[26]</sup> *The Urbanization of Capital*, 1985;<sup>[27]</sup> *Spaces of Hope*, 2000;<sup>[28]</sup> *Spaces of Capital*, 2001;<sup>[29]</sup> *Spaces of Neoliberalization*, 2005;<sup>[30]</sup> *The Enigma of Capital and the Crises of Capitalism*, 2010<sup>[31]</sup> ), elaborated Marx's thought on the systemic contradictions of capitalism, particularly in relation to the production of the urban environment (and to the production of space more broadly). He developed the notion that capitalism finds a "spatial fix"<sup>[32]</sup> for its periodic crises of overaccumulation through investment in fixed assets of infrastructure, buildings, etc.: "The built environment that constitutes a vast field of collective means of production and consumption absorbs huge amounts of capital in both its construction and its maintenance. Urbanisation is one way to absorb the capital surplus".<sup>[33]</sup> While the creation of the built environment can act as a form of crisis displacement, it can also constitute a limit in its own right, as it tends to freeze productive forces into a fixed spatial form. As capital cannot abide a limit to profitability, ever more frantic forms of "time-space compression"<sup>[34]</sup> (increased speed of turnover, innovation of ever faster transport and communications' infrastructure, "flexible accumulation"<sup>[35]</sup> ) ensue, often impelling technological innovation. Such innovation, however, is a double-edged sword:

The effect of continuous innovation [...] is to devalue, if not destroy, past investments and labour skills. *Creative destruction* is embedded within the circulation of capital itself. Innovation exacerbates instability, insecurity, and in the end, becomes the prime force pushing capitalism into periodic paroxysms of crisis. [...] The struggle to maintain profitability sends capitalists racing off to explore all kinds of other possibilities. New product lines are opened up, and that means the creation of new wants and needs. Capitalists are forced to redouble their efforts to create new needs in others [...]. The result is to exacerbate insecurity and instability, as masses of capital and workers shift from one line of production to another, leaving whole sectors devastated [...]. The drive to relocate to more advantageous places (the geographical movement of both capital and labour) periodically revolutionizes the international and territorial division of labour, adding a vital geographical dimension to the insecurity. The resultant transformation in the experience of space and place is matched by revolutions in the time dimension, as capitalists strive to reduce the turnover time of their capital to "the twinkling of an eye".<sup>[36]</sup>

Globalization can be viewed as some ultimate form of time-space compression, allowing capital investment to move almost instantaneously from one corner of the globe to another, devaluing fixed assets and laying off labour in one urban conglomeration while opening up new centres of manufacture in more profitable sites for production operations. Hence, in this continual process of creative destruction, capitalism does not resolve its contradictions and crises, but merely "moves them around geographically".<sup>[37]</sup>

## Marshall Berman

In his 1987 book *All That is Solid Melts into Air: The Experience of Modernity*,<sup>[7]</sup> particularly in the chapter entitled "Innovative Self-Destruction" (pp. 98–104), Marshall Berman provides a reading of Marxist "creative destruction" to explain key processes at work within modernity. The title of the book is taken from a well-known passage from *The Communist Manifesto*. Berman elaborates this into something of a *Zeitgeist* which has profound social and cultural consequences:

The truth of the matter, as Marx sees, is that everything that bourgeois society builds is built to be torn down. "All that is solid" — from the clothes on our backs to the looms and mills that weave them, to the men and women who work the machines, to the houses and neighborhoods the workers live in, to the firms and corporations that exploit the workers, to the towns and cities and whole regions and even nations that embrace them all — all these are made to be broken tomorrow, smashed or shredded or pulverized or dissolved, so they can be recycled or replaced next week, and the whole process can go on again and again, hopefully forever, in ever more profitable forms. The pathos of all bourgeois monuments is that their material strength and solidity actually count for nothing and carry no weight at all, that they are blown away like frail reeds by the very forces of capitalist development that they celebrate. Even the most beautiful and impressive bourgeois buildings and public works are disposable, capitalized for fast depreciation and planned to be obsolete, closer in their social functions to tents and encampments than to "Egyptian pyramids, Roman aqueducts, Gothic cathedrals".<sup>[38]</sup>

Here Berman emphasizes Marx's perception of the fragility and evanescence of capitalism's immense creative forces, and makes this apparent contradiction into one of the key explanatory figures of modernity.

## Manuel Castells

The renowned sociologist Manuel Castells, in his trilogy on *The Information Age* (the first volume of which, *The Rise of the Network Society*, appeared in 1996),<sup>[8]</sup> reinterpreted the processes by which capitalism invests in certain regions of the globe, while divesting from others, using the new paradigm of "informational networks". In the era of globalization, capitalism is characterized by near-instantaneous flow, creating a new spatial dimension, "the space of flows".<sup>[39]</sup> While technological innovation has enabled this unprecedented fluidity, this very process makes redundant whole areas and populations who are bypassed by informational networks. Indeed, the new spatial form of the mega-city or megalopolis, is defined by Castells as having the contradictory quality of being "globally connected and locally disconnected, physically and socially".<sup>[40]</sup> Castells explicitly links these arguments to the notion of creative destruction:

The "spirit of informationalism" is the culture of "creative destruction" accelerated to the speed of the optoelectronic circuits that process its signals. Schumpeter meets Weber in the cyberspace of the network enterprise.<sup>[41]</sup>

## Others

In 1992, the idea of creative destruction was put into formal mathematical terms by Philippe Aghion and Peter Howitt in their paper "A Model of Growth through Creative Destruction," published in *Econometrica*.

In 1995, Harvard Business School authors Richard L. Nolan and David C. Croson released *Creative Destruction: A Six-Stage Process for Transforming the Organization*. The book advocated downsizing to free up slack resources, which could then be reinvested to create competitive advantage.

More recently, the idea of "creative destruction" was utilized by Max Page in his 1999 book, *The Creative Destruction of Manhattan, 1900-1940*. The book traces Manhattan's constant reinvention, often at the expense of preserving a concrete past. Describing this process as "creative destruction," Page describes the complex historical circumstances, economics, social conditions and personalities that have produced crucial changes in Manhattan's

cityscape.

Neoconservative author Michael Ledeen argued in his 2002 book *The War Against the Terror Masters* that America is a revolutionary nation, undoing traditional societies: "Creative destruction is our middle name, both within our own society and abroad. We tear down the old order every day, from business to science, literature, art, architecture, and cinema to politics and the law." His characterization of creative destruction as a model for social development has met with fierce opposition from paleoconservatives.<sup>[42]</sup>

## Alternative name

Per the following text, this process is also known as Schumpeter's Gale:

The opening up of new markets and the organizational development from the craft shop and factory to such concerns as US Steel illustrate the process of industrial mutation that incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one ... [The process] must be seen in its role in the perennial gale of creative destruction; it cannot be understood on the hypothesis that there is a perennial lull.

—Joseph Schumpeter, *The Process of Creative Destruction*, 1942

## Media reflections of creative destruction

The film *Other People's Money* provides contrasting views of creative destruction, presented in two speeches regarding the takeover of a publicly-traded wire and cable company in a small New England town. One speech is by a corporate raider, and the other is given by the company CEO, who is principally interested in protecting his employees and the town.<sup>[43]</sup>

## References

- [1] Marx, Karl; Engels, Friedrich (2002) [1848]. *The Communist Manifesto* (<http://books.google.co.uk/books?id=CY3b0mcDF9QC>). Moore, Samuel (trans. 1888). Harmondsworth, UK: Penguin. p. 226. ISBN 0-14-044757-1. . Retrieved 2010-11-07.
- [2] Marx, Karl (1993) [1857]. *Grundrisse: Foundations of the Critique of Political Economy (rough draft)* (<http://books.google.co.uk/books?id=bDyemaqiZjUC>). Nicolaus, Martin (trans. 1973). Harmondsworth, UK: Penguin. p. 750. ISBN 0-14-044575-7. . Retrieved 2010-11-07.
- [3] Marx, Karl (1969) [1863]. *Theories of Surplus-Value: "Volume IV" of Capital* (<http://books.google.co.uk/books?id=sU23AAAAIAAJ>). 2. London: Lawrence & Wishart. pp. 495–96. . Retrieved 2010-11-10.
- [4] Reinert, Hugo; Reinert, Erik S. (2006). "Creative Destruction in Economics: Nietzsche, Sombart, Schumpeter" (<http://www.springerlink.com/content/j0g1348m35327v04/>). , Word document ([http://www.othercanon.org/uploads/Nietzsche Creative Destruction in Economics f.doc](http://www.othercanon.org/uploads/Nietzsche%20Creative%20Destruction%20in%20Economics%20f.doc))
- [5] Discussing the way in which the destruction of forests in Europe laid the foundations for nineteenth-century capitalism, Sombart writes: "Wiederum aber steigt aus der Zerstörung neuer schöpferischer Geist empor" ("Again, however, from destruction a new spirit of creation arises"). Sombart, Werner (1913) (in German). *Krieg und Kapitalismus* ([http://www.archive.org/stream/kriegundkapitali00sombuoft/kriegundkapitali00sombuoft\\_djvu.txt](http://www.archive.org/stream/kriegundkapitali00sombuoft/kriegundkapitali00sombuoft_djvu.txt)). München. p. 207. ISBN 0405065396. . Retrieved 2010-11-07.
- [6] Harvey, David (2007) [1982]. *Limits to Capital* (<http://books.google.co.uk/books?id=KtAdAQAAIAAJ>) (2nd ed.). London: Verso. pp. 200–03. ISBN 1-84467-095-3. . Retrieved 2010-11-07.
- [7] Berman, Marshall (1988). *All that is Solid Melts into Air: The Experience of Modernity* (<http://books.google.co.uk/books?id=mox1ywyhtgC>). Ringwood, Vic: Viking Penguin. ISBN 0-86091-785-1. . Retrieved 2010-11-07.
- [8] Castells, Manuel (2000) [1996]. *The Rise of the Network Society* (<http://books.google.co.uk/books?id=hngg4aFtJVcC>) (2nd ed.). Oxford: Blackwell Publishers. ISBN 0-631-22140-9. . Retrieved 2010-11-07.
- [9] For further discussion of the concept of creative discussion in the Grundrisse, see Elliott, J. E. (1978). "Marx's "Grundrisse": Vision of Capitalism's Creative Destruction" (<http://jstor.org/stable/4537475>). *Journal of Post Keynesian Economics* 1 (2): 148–169. .
- [10] Marx, Karl (1969) [1863]. *Theories of Surplus-Value: "Volume IV" of Capital* (<http://books.google.co.uk/books?id=sU23AAAAIAAJ>). 2. pp. 495–96. . For further explanation of these quotations see Harvey, David (2007) [1982]. *Limits to Capital* (<http://books.google.co.uk/books?id=KtAdAQAAIAAJ>). pp. 200–03. ISBN 1-84467-095-3. .
- [11] Harris, Abram L. (1942). "Sombart and German (National) Socialism" (<http://www.jstor.org/stable/1826617>). *Journal of Political Economy* 50 (6): 805–835 (807). doi:10.1086/255964. .

- [12] Harvey, David (2010). *The Enigma of Capital and the Crises of Capitalism* (<http://books.google.com/books?id=ww1dPgAACAAJ>). London: Profile Books. p. 46. ISBN 1-84668-308-4. . Retrieved 2010-11-10.
- [13] Sombart, W., 1913, *Krieg und Kapitalismus*, (War and Capitalism) Leipzig: Duncker & Humblot, p. 207
- [14] Bradbury, Malcolm; McFarlane, James (1976). *Modernism 1890-1930* (<http://books.google.com/books?id=aZlGcAAACAAJ>). Harmondsworth, UK: Penguin. p. 446. .
- [15] The Reaction in Germany, From the Notebooks of a Frenchman (<http://www.marxists.org/reference/archive/bakunin/works/1842/reaction-germany.htm>), October 1842
- [16] "\$200 Laptops Break a Business Model" (<http://www.nytimes.com/2009/01/26/technology/26spend.html?partner=rss&emc=rss>). *New York Times*. January 25, 2009. . Retrieved 2009-01-27. "Indeed, Silicon Valley may be one of the few places where businesses are still aware of the ideas of Joseph Schumpeter, an Austrian economist who wrote about business cycles during the first half of the last century. He said the lifeblood of capitalism was "creative destruction." Companies rising and falling would unleash innovation and in the end make the economy stronger."
- [17] Schumpeter, J. A. (1949): The historical approach to the analysis of business cycles, in *Essays: On Entrepreneurs, Innovations, Business Cycles, and the Evolution of Capitalism*, New Brunswick, N.J. and London: Transaction, p. 349. As quoted by "Schumpeter and Regional Innovation" by Esben S. Andersen. Chapter for *Handbook of Regional Innovation and Growth*. (ed. P. Cooke, Elgar Publ.)
- [18] Surviving the Gales of Creative Destruction: The Determinants of Product Turnover ([http://faculty.london.edu/mkyle/SMJ\\_revision\\_Sept\\_2004.pdf](http://faculty.london.edu/mkyle/SMJ_revision_Sept_2004.pdf)), John M. de Figueiredo & Margaret K. Kyle, 12 September 2004.
- [19] Creative Destruction and Innovation in The News Industry (<http://johngaynardcreativity.blogspot.com/2009/01/christian-science-monitor-is-to.html>) John Gaynard's blog, January 21, 2009.
- [20] Richman, Dan; James, Andrea (2009-03-16). "Seattle P-I to publish last edition Tuesday" ([http://www.seattlepi.com/business/403793\\_piclosure17.html](http://www.seattlepi.com/business/403793_piclosure17.html)). *Seattle Post-Intelligencer*. .
- [21] Could LinkedIn and Viadeo Creatively Destroy the Traditional French Networks? (<http://johngaynardcreativity.blogspot.com/2009/01/could-linkedin-and-viadeo-creatively.html>) John Gaynard's blog, January 13, 2009.
- [22] Richard R. Nelson, Katherine Nelson *Technology, institutions, and innovation systems*. *Research Policy* 31 (2002), p. 265-272.
- [23] Wells, David A. (1890). *Recent Economic Changes and Their Effect on Production and Distribution of Wealth and Well-Being of Society* ([http://books.google.com/?id=2V3qF4MWh\\_wC&printsec=frontcover&dq=RECENT+ECONOMIC+CHANGES+AND+THEIR+EFFECT+ON+DISTRIBUTION+OF+WEALTH+AND+WELL+BEING+OF+SOCIETY+WELLS#v=onepage&q&f=false](http://books.google.com/?id=2V3qF4MWh_wC&printsec=frontcover&dq=RECENT+ECONOMIC+CHANGES+AND+THEIR+EFFECT+ON+DISTRIBUTION+OF+WEALTH+AND+WELL+BEING+OF+SOCIETY+WELLS#v=onepage&q&f=false)). New York: D. Appleton and Co.. ISBN 0543724743. .
- [24] A History of American Agriculture 1776-1990 (<http://inventors.about.com/library/inventors/blfarm4.htm>) United States Department of Agriculture.
- [25] Harvey, David (2009) [1973]. *Social Justice and the City* (<http://books.google.com/books?id=VCwLi2nVmooC>). ISBN 9780820334035. .
- [26] Harvey, David (2006) [1982]. *The Limits to Capital* (<http://books.google.com/books?id=KtAdAQAAlAAJ>). ISBN 9781844670956. .
- [27] Harvey, David (1985). *The Urbanization of Capital: Studies in the History and Theory of Capitalist Urbanization* (<http://books.google.com/books?id=5lvaAAAAMAAJ>). ISBN 9780801831447. .
- [28] Harvey, David (2000). *Spaces of Hope* (<http://books.google.com/books?id=W00VHZg3u2MC>). ISBN 9780520225787. .
- [29] Harvey, David (2001). *Spaces of Capital: Towards a Critical Geography* (<http://books.google.com/books?id=EDRzPCb4Zd4C>). ISBN 9780415932417. .
- [30] Harvey, David (2005). *Spaces of Neoliberalization: Towards a Theory of Uneven Geographical Development* (<http://books.google.com/books?id=Z7sS53uqTJoC>). ISBN 9783515087469. .
- [31] Harvey, David (2010). *The Enigma of Capital and the Crises of Capitalism* (<http://books.google.com/books?id=ww1dPgAACAAJ>). London: Profile Books. ISBN 1-84668-308-4. . Retrieved 2010-11-10.
- [32] See in particular "The Spatial Fix: Hegel, Von Thünen and Marx", in Harvey, David (2001). *Spaces of Capital: Towards a Critical Geography* (<http://books.google.com/books?id=EDRzPCb4Zd4C>). pp. 284–311. ISBN 9780415932417. .
- [33] Harvey, David (2010). *The Enigma of Capital and the Crises of Capitalism* (<http://books.google.com/books?id=ww1dPgAACAAJ>). London: Profile Books. p. 85. ISBN 1-84668-308-4. . Retrieved 2010-11-10.
- [34] Harvey, David (1995). *The Condition of Postmodernity: an Enquiry into the Origins of Cultural Change* ([http://books.google.com/books?id=RAGeva8\\_EIMC](http://books.google.com/books?id=RAGeva8_EIMC)). pp. 240–323. ISBN 9780631162940. .
- [35] Harvey, David (1995). *The Condition of Postmodernity*. p. 147. ISBN 9780631162940.
- [36] Harvey, David (1995). *The Condition of Postmodernity*. pp. 105–06. ISBN 9780631162940.
- [37] David Harvey. (28th June 2010). *Crises of Capitalism* (<http://comment.rsblogs.org.uk/2010/06/28/rsa-animate-crisis-capitalism/>). [Webcast]. Royal Society for the encouragement of Arts, Manufactures and Commerce, London: RSA Animates. .
- [38] Berman, Marshall (1987). *All That is Solid Melts into Air*. p. 99.
- [39] Castells, Manuel. *The Rise of the Network Society*. pp. 376–428.
- [40] Castells, Manuel. *The Rise of the Network Society*. p. 404.
- [41] Castells, Manuel. *The Rise of the Network Society*. p. 199. For further discussion, see also Harding, Robert (March 2006). "Manuel Castells' Technocultural Epoch in "The Information Age"" (<http://www.jstor.org/stable/4241406>). *Science Fiction Studies* 33 (1): 18–29. ISSN 00917729. . Retrieved 2010-11-12.

- [42] John Laughland: Flirting with Fascism. Neocon theorist Michael Ledeen draws more from Italian fascism than from the American Right (<http://www.amconmag.com/article/2003/jun/30/00013/>) *American Conservative*, June 30, 2003.
- [43] Kenneth M. Braun: Capitalism's Finest Film (<http://www.mackinac.org/9170>) Macinac Center for Public Policy, December 27, 2007.

## External links

- Economy Historian and photographer Jan Jörnmarks page on creative destruction: <http://createdestruction.se/>

## Further reading

- Philippe Aghion and Peter Howitt. *A Model of growth through Creative Destruction*. *Econometrica* 60:2 (1992), pp. 323–51.
- Philippe Aghion and Peter Howitt. *Endogenous Growth Theory*. MIT Press. 1997.
- Edward Cheung, "Baby Boomers, Generation X and Social Cycles" ([http://www.longwavepress.com/baby\\_boomers\\_generation\\_x\\_1.htm](http://www.longwavepress.com/baby_boomers_generation_x_1.htm)). Long Wave Press. 1995, revised 2007.
- Clayton M. Christensen. "The Innovator's Dilemma" (<http://www.claytonchristensen.com/publications.html>). HarperBusiness. 2001.
- Richard Foster and Sarah Kaplan. "Creative Destruction: Why Companies that are Built to Last Underperform the Market - And how to Successfully Transform Them" (<http://www.mckinsey.com/ideas/books/createdestruction/index.asp>). Currency publisher. 2001.
- J. Stanley Metcalfe. *Evolutionary Economics and Creative Destruction (Graz Schumpeter Lectures, 1)*. Routledge. 1998.
- Richard L. Nolan and David C. Croson, *Creative Destruction: A Six-Stage Process for Transforming the Organization*. Harvard Business School Press. 1995.
- Max Page. *The Creative Destruction of Manhattan, 1900-1940*. University of Chicago Press. 1999.
- Hugo Reinert and Erik S. Reinert. "Creative Destruction in Economics: Nietzsche, Sombart, Schumpeter." (<http://www.othercanon.org/papers/more.asp?id=30>) In J.G. Backhaus and W. Drechsler, eds. *Friedrich Nietzsche: Economy, and Society*. Springer. 2006.
- Joseph A. Schumpeter. *Capitalism, Socialism and Democracy* (New York: Harper, 1975) [orig. pub. 1942]
- Thomas G. Osenton. *The Death of Demand: Finding Growth in a Saturated Global Economy* (New Jersey: Financial Times Prentice Hall, 2004)
- James M. Utterback. *Mastering the Dynamics of Innovation*. Harvard Business School Press. 1996.
- Roger D. Smith. "The Disruptive Potential of Game Technologies: Lessons Learned from its Impact on the Military Simulation Industry" ([http://www.modelbenders.com/papers/DisruptivePotential\\_RTM.pdf](http://www.modelbenders.com/papers/DisruptivePotential_RTM.pdf)). *Research Technology Management* 50:Sept-Oct (2006), pp. 57–64.
- Thomas Homer-Dixon. *Upside of Down: Catastrophe, Creativity, and the Renewal of Civilization* (<http://www.theupsideofdown.com/>). Island Press. 2006.











MattiG69, Mattisgoo, Maxamegalon2000, Maxis ftw, McSly, Me lkjhgfdsa, Mechasheherezada, MemeGeneScene, Merla25, Merope, Merovingian, Mhazard9, Michael Hardy, Michaelbusch, Michelleem, Micru, Midgrid, Mifter, Mike Klaassen, Mithent, Mjpieters, Mnmx, Modulatum, Mombartz, Morrad, Mortzestus, Mr Bungle, Musicalone, N5ilm, NAT1V3, NATO.Caliber, Nagy, NawlinWiki, Neko-chan, Netizen, Netrapt, Netsnippe, Neverquick, NewEnglandYankee, Nguyễn Thanh Quang, Nifky?, Nivix, Nn123645, Noctibus, Notnd, Ntennis, Nysalor, O.Duke, OKingMonkey, Odie5533, Ojay123, Onekopaka, Onorem, Orange Suede Sofa, Orannis, Ori, Ortolan88, OwenX, Oxymoron83, Parletre, Pascal666, Patrick, Paul August, Paul Erik, Pcb21, Pdcok, Pturney, Peacearena, Peak Freak, Perfect Proposal, Peter Pan, Pkg, Philip Trueman, Piano non troppo, Pilotguy, Pinethicket, Pinkadelica, Piotrus, Pitan, Polyparadigm, Pottypat, Prashanthns, Prestonmarkstone, PrettyPoison, Prodego, Proxima Centauri, PseudoOne, Psy guy, Psychlohexane, Puffin, QueenCake, Quintote, Qxz, R Calvete, RA0808, RJaguar3, Radicaledwardflo, Radon210, RandomP, Ranveig, Razorflame, Rdsmith4, Red, Red Bowen, Rettetast, RexNL, Riversider2008, Robertkeller, Robomaeheyem, Rolf-Peter Wille, Ronhjones, Rory096, Rrburke, Rror, Ruiner73, Ryan-McCulloch, Ryguasu, S3000, SMC, SQGibbon, Samwaltz, Sango123, Satanael, Scarian, Scopia, Sceptre, SchfiftyThree, Scientizzle, Seramai, ShadowRangerRIT, Shadowjams, ShakingSpirit, Shanes, Shantavira, Sicaruma, Silentaria, Silversmith, Sinatra, Sintaku, Sionus, Sjö, Skata\*d, Skipnicholson, SkyWalker, Slakr, Sliffa, Slightsmile, Snow Eater, Snowolf, SoWhy, Soliloquial, Some jerk on the Internet, Sophia, South Bay, Spartan-James, Spellmaster, Spontaneous generation, SpookyMulder, Squeemu, SquidSK, Staffwaterboy, Starnestommy, Stefanomione, Stellmach, Stickee, Stormie, Subversive.sound, SunDog, Sundar, SupermanReturns, Supertouch, Susan C.Strong, Symane, Synchronism, TATOLPREP, Tanaats, Tango, Tarquin, Tatkinu, Tb149208, Tbo 157, Tcncv, Techman224, That Guy, From That Show!, The Thing That Should Not Be, The Wednesday Island, The wub, TheThingy, Thingg, Thohstadt, Thomas Mills Hinkle, Tide rolls, Tigerclaw221, Tim Q. Wells, Tim Shell, Titoxd, Toddst1, Todwyer, Tohd8BohaithuGh1, Tom Gore, Tom harrison, Tommy2010, Tone, Trevor MacInnis, Trusilver, TubularWorld, Twigg17, Twinsday, UED77, Urbane Legend, Useight, User2004, Usuallylucid, VMS Mosaic, Vaganyik, Vani chan, Vanierter, Vanished user 01, Vanished user 03, Veinor, Velho, Versus22, Vickaul, Viriditas, Vivio Testarossa, Volatilmolotov, Voyagerfan5761, Vrenator, Vrrad, Vzbs34, WDavis1911, WODUP, Waggers, Wahrmund, Wailmer1997, Wasabiroot, Waveguy, Wavelength, Wayfarers43, Wayne Slam, Werdan7, Weregerebil, West.andrew.g, Wetman, Wherenow, Why Not A Duck, WikHead, Wikieditor06, WikipedianMarlith, Wikipelli, Wikivangelist, William Avery, Willy brown, Wimt, Wknight94, Wolfdog, Wolfnix, Wtmitchell, Wzf09iwzd, XDaniex, Xaosflux, Xingzeng, Xompanthy, Xurich, Yansa, Yellow Evan, Yidisheryid, Youandme, Your grey blue eyes, YourEyesOnly, Yrrah, Zandperl, Zaynabasdghjklpoiuybnm, Zenity, Zeno Gantner, Zenohockey, Zuchinni one, ZuilSerip, Zukeeper, 2080 anonymous edits

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